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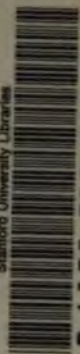
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TRANSACTIONS

OF

THE FEDERATED INSTITUTION

OF

MINING ENGINEERS.

VOL. XIII.—1896-97.

EDITED BY M. WALTON BROWN, SECRETARY.

NEWCASTLE-UPON-TYNE: PUBLISHED BY THE INSTITUTION.

PRINTED BY ANDREW REID & CO., LIMITED, NEWCASTLE-UPON-TYNE.
1898.

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ANY PUBLICATION OF A FEDERATED INSTITUTE MAY BE PLACED AT THE END OF THE VOLUME, i.e., "ANNUAL REPORT," "LIST OF MEMBERS," ETC., ETC.

THE FEDERATED INSTITUTION OF MINING ENGINEERS.

FOUNDED JULY 1ST, 1889.

BYE-LAWS

Passed at Council Meeting held on May 28th, 1891.

I.—CONSTITUTION.

1.—The Federated Institution of Mining Engineers shall consist of all or any of the societies interested in the advancement of mining, metallurgy, engineering, and their allied industries, who shall from time to time join together and adhere to the Bye-Laws.

2.—The Institution shall have for its objects—

- (a) The advancement and encouragement of the sciences of mining, metallurgy, engineering, and their allied industries.
- (b) The interchange of opinions, by the reading of communications from members and others, and by discussions at general meetings, upon improvements in mining, metallurgy, engineering, and their allied industries.
- (c) The publication of original communications, discussions, and other papers connected with the objects of the Institution.
- (d) The purchase and disposal of real and personal property for such objects.
- (e) The performance of all things connected with or leading to the purpose of such objects.

3.—The offices of the Institution shall be in Newcastle-upon-Tyne, or such other place as shall be from time to time determined by resolution of the Council.

4.—The year of the Institution shall end on July 31st in every year.

5.—The affairs and business of the Institution shall be managed and controlled by the Council.

II.—MEMBERSHIP.

6.—The original adherents or founders are as follows :—

- (a) Chesterfield and Midland Counties Institution of Engineers, Chesterfield.
- (b) Midland Institute of Mining, Civil, and Mechanical Engineers, Barnsley.
- (c) North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne.
- (d) South Staffordshire and East Worcestershire Institute of Mining Engineers, Birmingham.

7.—Written applications from societies to enter the Institution shall be made to the Council, by the President of the applying society, who shall furnish any information that may be desired by the Council.

8.—A.—If desired by the Council, any of the Federated Institutes shall revise their Bye-Laws, in order that their members shall consist of Ordinary Members, Associate Members, and Honorary Members, with Associates and Students, and section B following shall be a model Bye-Law to be adopted by any society when so desired by the Council.

B.—“The members shall consist of Ordinary Members, Associate Members, and Honorary Members, with Associates and Students :—

- (a) Each Ordinary Member shall be more than twenty-three years of age, have been regularly educated as a mining, metallurgical, or mechanical engineer, or in some other branch of engineering, according to the usual routine of pupilage, and have had subsequent employment for at least two years in some responsible situation as an engineer; or if he has not undergone the usual routine of pupilage, he must have been employed or have practised as an engineer for at least five years.
- (b) Each Associate Member shall be a person connected with or interested in mining, metallurgy, or engineering, and not practising as a mining, metallurgical, or mechanical engineer, or some other branch of engineering.
- (c) Each Honorary Member shall be a person who has distinguished himself by his literary or scientific attainments, or who may have made important communications to any of the Federated Institutes.
- (d) Associates shall be persons acting as under-viewers, under-managers, or in other subordinate positions in mines or metallurgical works, or employed in analogous positions in other branches of engineering.
- (e) Students shall be persons who are qualifying themselves for the profession of mining, metallurgical, or mechanical engineering, or other branch of engineering, and such persons may continue Students until they attain the age of twenty-five years."

9.—The Ordinary Members, Associate Members, and Honorary Members, Associates and Students shall have notice of, and the privilege of attending, the ordinary and annual general meetings, and shall receive all publications of the Institution. They may also have access to, and take part in, the general meetings of any of the Federated Institutes.

10.—The members of any Federated Institute, whose payments to the Institution are in arrear, shall not receive the publications and other privileges of the Institution.

11.—After explanations have been asked by the President from any Federated Institute, whose payments are in arrear, and have not been paid within one month after written application by the Secretary, the Council may decide upon its suspension or expulsion from the Institution; but such suspension or expulsion shall only be decided at a meeting attended by at least two-thirds of the members of the Council by a majority of three-fourths of the members present.

III.—SUBSCRIPTIONS.

12.—Each of the Federated Institutes shall pay fifteen shillings per annum for each Ordinary Member, Associate Member, Honorary Member, Associate, and Student, or such other sum, and in such instalment or instalments as may be determined from time to time by resolution or resolutions of the Council. Persons joining any of the Federated Institutes during the financial year of the Federated Institution shall be entitled to all publications issued for that year, after his election is notified to the Secretary, and the instalment or instalments due on his behalf have been paid.

IV.—ELECTION OF OFFICERS AND COUNCIL.

13.—The officers of the Institution, other than the Secretary and Treasurer, shall consist of Councillors elected annually prior to August in each year, by and out of the Ordinary Members and Associate Members of each Federated Institute, in the proportion of one Councillor per forty Ordinary Members or Associate Members thereof; of Vice-Presidents elected by and from the Council at their first meeting in each year on behalf of each Institute, in the proportion of one

Vice-President per two hundred Ordinary Members or Associate Members thereof ; and of a President elected by and from the Council at their first meeting in each year ; who, with the Local Secretaries of each Federated Institute and the Secretary and Treasurer, shall form the Council. All Presidents on retiring from that office shall be *ex-officio* Vice-Presidents so long as they continue Ordinary Members or Associate Members of any of the Federated Institutes.

14.—In case of the decease, expulsion, or resignation of any officer or officers, the Council may, if they deem it requisite, fill up the vacant office or offices at their next meeting.

V.—DUTIES OF OFFICERS AND COUNCIL.

15.—The Council shall represent the Institution and shall act in its name, and shall make such calls upon the Federated Institutes as they may deem necessary, and shall transact all business and examine accounts, authorise payments and may invest or use the funds in such manner as they may from time to time think fit, in accordance with the objects and Bye-Laws of the Institution.

16.—The Council shall decide the question of the admission of any society, and may decree the suspension or expulsion of any Federated Institute for non-payment of subscriptions.

17.—The Council shall decide upon the publication of any communications.

18.—There shall be three ordinary meetings of the Council in each year, on the same day as, but prior to, the ordinary or annual general meetings of the members.

19.—A special meeting of the Council shall be called whenever the President may think fit, or upon a requisition to the Secretary signed by ten or more of its members, or by the President of any of the Federated Institutes. The business transacted at a special meeting of the Council shall be confined to that specified in the notice convening it.

20.—The meetings of the Council shall be called by circular letter, issued to all the members at least seven days previously, accompanied by an agenda paper, stating the nature of the business to be transacted.

21.—The order in which business shall be taken at the ordinary and annual general meetings may be, from time to time, decided by the Council.

22.—The Council may communicate with the Government in cases of contemplated or existing legislation, of a character affecting the interests of mining, metallurgy, engineering, or their allied industries.

23.—The Council may appoint Committees, consisting of members of the Institution, for the purpose of transacting any particular business, or of investigating any specific subject connected with the objects of the Institution.

24.—A Committee shall not have power or control over the funds of the Institution, beyond the amount voted for its use by the Council.

25.—Committees shall report to the Council, who shall act thereon and make use thereof as they may elect.

26.—The President shall take the chair at all meetings of the Institution, the Council, and Committees at which he may be present.

27.—In the absence of the President, it shall be the duty of the senior Vice-President present to preside at the meetings of the Institution. In case of the absence of the President and of all the Vice-Presidents, the meeting may elect any member of Council, or in case of their absence any Ordinary Member or Associate Member to take the chair at the meeting.

28.—At meetings of the Council six shall be a quorum.

29.—Every question shall be decided at the meetings of the Council by the votes of the majority of the members present. In case of equal voting, the President, or other member presiding in his absence, shall have a casting vote. Upon the request of two members, the vote upon any question shall be by ballot.

30.—The Secretary shall be appointed by and shall act under the direction and control of the Council. The duties and salary of the Secretary shall be fixed and varied from time to time at the will of the Council.

31.—The Secretary shall summon and attend all meetings of the Council, and the ordinary and annual general meetings of the Institution, and shall record the proceedings in the minute book. He shall direct the administrative and scientific publications of the Institution. He shall have charge of and conduct all correspondence relative to the business and proceedings of the Institution, and of all committees where necessary, and shall prepare and issue all circulars to the members.

32.—One and the same person may hold the office of Secretary and Treasurer.

33.—The Treasurer shall be appointed annually by the Council at their first meeting in each year. The income of the Institution shall be received by him, and shall be paid into Messrs. Lambton & Co.'s bank at Newcastle-upon-Tyne, or such other bank as may be determined from time to time by the Council.

34.—The Treasurer shall make all payments on behalf of the Institution, by cheques signed by two members of Council, the Treasurer, and the Secretary after payments have been sanctioned by Council.

35.—The surplus funds may, after resolution of the Council, be invested in Government securities, in railway and other debenture shares such as are allowed for investment by trustees, in the purchase of land, or in the purchase, erection, alteration, or furnishing of buildings for the use of the Institution. All investments shall be made in the names of Trustees appointed by the Council.

36.—The accounts of the Treasurer and the financial statement of the Council shall be audited and examined by a chartered accountant, appointed by the Council at their first meeting in each year. The accountants' charges shall be paid out of the funds of the Institution.

37.—The minutes of the Council's proceedings shall at all times be open to the inspection of the Ordinary Members and Associate Members.

VI.—GENERAL MEETINGS.

38.—An ordinary general meeting shall be held in February, May, and September, unless otherwise determined by the Council; and the ordinary general meeting in the month of September shall be the annual general meeting at which a report of the proceedings, and an abstract of the accounts of the previous year ending July 31st, shall be presented by the Council. The ordinary general meeting in the month of May shall be held in London, at which the President may deliver an address.

39.—Invitations may be sent by the Secretary to any person whose presence at discussions shall be thought desirable by the Council, and persons so invited shall be permitted to read papers and take part in the proceedings and discussions.

40.—Discussion may be invited on any paper published by the Institution, at meetings of any of the Federated Institutes, at which the writer of the paper may be invited to attend. Such discussion, however, shall in all cases be submitted to the writer of the paper before publication, and he may append a reply at the end of the discussion.

VII.—PUBLICATIONS.

41.—The publications may comprise:—

- (a) Papers upon the working of mines, metallurgy, engineering, railways and the various allied industries.
- (b) Papers on the management of industrial operations.
- (c) Abstracts of foreign papers upon similar subjects.
- (d) An abstract of the patents relating to mining and metallurgy, etc.
- (e) Notes of questions of law concerning mines, manufactures, railways, etc.

42.—Each paper (with complete drawings, if any, to scale), to be read at any meeting of the Institution or of any of the Federated Institutes, shall be placed in the hands of the Secretary at least fourteen days before the date of the meeting at which the paper is to be read, and shall, subject to the approval of the Council, be printed, together with any discussion or remarks thereon.

43.—The Council may accept communications from persons who are not members of the Institution and allow them to be read at the ordinary or annual general meetings.

44.—No paper which has already been published (except as provided for in Bye-Law 41) shall appear in the publications of the Institution.

45.—A paper in course of publication cannot be withdrawn by the writer.

46.—Proofs of all papers and reports of discussions forwarded to any person for revision must be returned to the Secretary within seven days from the date of their receipt, otherwise they will be considered correct and be printed off.

47.—The copyright of all papers accepted for printing by the Council shall become vested in the Institution, and such communications shall not be published for sale or otherwise without the written permission of the Council.

48.—Twenty copies of each paper and the accompanying discussion shall be presented to the writer free of cost. He may also obtain additional copies upon payment of the cost to the Secretary, by an application attached to his paper. These copies must be unaltered copies of the paper as appearing in the publication of the Institution, and the cover shall state that it is an "Excerpt from the Transactions of The Federated Institution of Mining Engineers."

49.—The Federated Institutes may receive copies of their own portion of the publications in respect of such of their members as do not become members of the Federated Institution, and shall pay 10s. per annum in respect of every copy so supplied; and similar copies for exchanges shall be paid for at cost price.

50.—The Local Secretary of each Federated Institute shall prepare and edit all papers and discussions of such Institute, and promptly forward them to the Secretary, who shall submit proofs to the Local Secretary before publication.

51.—A list of the members, with their last known addresses, shall be printed in the publications of the Institution.

52.—The publications of the Institution shall only be supplied to members, and no duplicate copies of any portion of the publications shall be issued to any member or Federated Institute unless by order of the Council.

53.—The annual volume or volumes of the publications may be sold, in the complete form only, at such prices as may be determined from time to time by the Council; to non-members for not less than £3; and to members who are desirous of completing their sets of the publications, for not less than 15s.

54.—The Institution as a body is not responsible for the statements and opinions advanced in the papers which may be read or in the discussions which may take place at the meetings of the Institution, or of the Federated Institutes.

VIII.—MEDALS AND OTHER REWARDS.

55.—The Council may award annually the sum of twenty pounds, in the form of medals or other rewards, to the authors of papers published by the Institution.

IX.—PROPERTY.

56.—The capital fund shall consist of such amounts as shall from time to time be determined by resolution of the Council.

57.—The Institution may make use of the following receipts for its expenses :—

- (a) The interest of its accumulated capital fund ;
- (b) The annual subscriptions ; and
- (c) Receipts of all other descriptions.

58.—The Institution may form a collection of papers, books, and models.

59.—Societies or members who may have ceased their connexion with the Institution shall have no claim to participate in any of its properties.

60.—All donations to the Institution shall be acknowledged in the annual report of the Council.

X.—ALTERATION OF BYE-LAWS.

61.—No alteration shall be made in the Bye-Laws of the Institution, except at a special meeting of the Council called for that purpose, and the particulars of every such alteration shall be announced at their previous meeting, and inserted in the minutes, and shall be sent to all members of Council at least fourteen days previous to such special meeting, and such special meeting shall have power to adopt any modification of such proposed alteration of the Bye-Laws, subject to confirmation by the next ensuing Council meeting.

THE FEDERATED INSTITUTION OF MINING ENGINEERS.

OFFICERS, 1896-97.

President.

Sir LINDSAY WOOD, Bart., The Hermitage, Chester-le-Street.

Vice-Presidents.

- Mr. J. B. ATKINSON, H.M. Inspector of Mines, 10, Foremount Terrace, Glasgow.
 Mr. W. N. ATKINSON, H.M. Inspector of Mines, Barlaston, Stoke-upon-Trent (Past-President).
 Mr. EMERSON BAINERIDGE, 4, Whitehall Court, London, S.W.
 Sir LOWTHIAN BELL, Bart., Rounton Grange, Northallerton.
 Mr. WILLIAM COCHRANE, St. John's Chambers, Grainger Street West, Newcastle-upon-Tyne.
 Mr. JOHN DAGLISH, Rothley Lake, Cambo, R.S.O., Northumberland.
 Mr. JAMES S. DIXON, Fairleigh, Bothwell, N.B.
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 Mr. GEORGE LEWIS, Albert Street, Derby (Past-President).
 Sir WILLIAM THOMAS LEWIS, Bart., Mardy, Aberdare.
 Mr. GEORGE MAY, The Harton Collieries, South Shields.
 Mr. M. H. MILLS, Sherwood Hall, Mansfield.
 Mr. GEORGE A. MITCHELL, 5, West Regent Street, Glasgow (Past-President).
 Mr. JOHN NEVIN, Littlemoor House, Mirfield.
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 Mr. EDWARD B. WAIN, Whitfield Collieries, Norton-in-the-Moors, Stoke-upon-Trent.
 Mr. GEORGE BLAKE WALKER, Wharnccliffe Silkstone Colliery, Barnsley.

Council.

* Deceased.

- Mr. HENRY AYTON, 122, Rye Hill, Newcastle-upon-Tyne.
 Mr. JAMES BARROWMAN, Staneacre, Hamilton, N.B.
 Mr. T. W. BENSON, 24, Grey Street, Newcastle-upon-Tyne.
 Mr. G. J. BINNS, Netherseal Colliery, Burton-upon-Trent.
 Mr. W. C. BLACKETT, Acorn Close, Sacriston, Durham.
 Mr. M. WALTON BROWN, 10, Lambton Road, Newcastle-upon-Tyne.
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 Mr. T. E. FORSTER, 3, Eldon Square, Newcastle-upon-Tyne.
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 Mr. JAMES HAMILTON, 208, St. Vincent Street, Glasgow.
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 Mr. JEREMIAH HEAD, 47, Victoria Street, Westminster, London, S.W.
 Mr. WILLIAM HEATH, Edgefields House, Stockton Brook, Stoke-upon-Trent.
 Mr. J. L. HEDLEY, H.M. Inspector of Mines, 2, Devonshire Terrace, Newcastle-upon-Tyne.
 Mr. W. F. HOWARD, 15, Cavendish Street, Chesterfield.
 Mr. JOHN JACKSON, Stubben Edge, Chesterfield.
 Mr. A. C. KAYLL, Gosforth, Newcastle-upon-Tyne.
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 Mr. T. W. H. MITCHELL, Mining Offices, Barnsley.
 *Mr. RALPH MOORE, 13, Clairmont Gardens, Glasgow.
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 Mr. T. O. ROBSON, Chowdene Cottage, Low Fell, Gateshead-upon-Tyne.
 Mr. J. M. RONALDSON, H.M. Inspector of Mines, 44, Athole Gardens, Glasgow.
 Mr. FRED. J. ROWAN, 121, West Regent Street, Glasgow.
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 Mr. JOHN STRICK, Bar Hill, Madeley, Staffordshire.
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 Mr. FRANK N. WARDELL, H.M. Inspector of Mines, Wath-upon-Deane, near Rotherham.
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 Mr. W. O. WOOD, South Hetton, Sunderland.

Auditor.

Mr. JOHN G. BENSON, Newcastle-upon-Tyne.

Treasurer.

Mr. REGINALD GUTHRIE, Neville Hall, Newcastle-upon-Tyne.

Secretary.

Mr. M. WALTON BROWN, Neville Hall, Newcastle-upon-Tyne.

LIST OF MEMBERS.

Honorary Members.

* Deceased.

The Federated Institution of Mining Engineers.

- J. B. ATKINSON, H.M. Inspector of Mines, 10, Foremount Terrace, Glasgow.
 W. N. ATKINSON, H.M. Inspector of Mines, Barlaston, Stoke-upon-Trent.
 R. DONALD BAIN, H.M. Inspector of Mines, Springwell Hall, Durham.
 W. BEATTIE-SCOTT, H.M. Inspector of Mines, Park Avenue, Handsworth, near Birmingham.
 C. LE NEVE FOSTER, H.M. Inspector of Mines, Llandudno.
 JOHN GERRARD, H.M. Inspector of Mines, Worsley, Manchester.
 HENRY HALL, H.M. Inspector of Mines, Rainhill, Lancashire.
 J. L. HEDLEY, H.M. Inspector of Mines, 2, Devonshire Terrace, Newcastle-upon-Tyne.
 J. S. MARTIN, H.M. Inspector of Mines, The Vikings, 16, Durdham Park, Bristol.
 JOSEPH T. ROBSON, H.M. Inspector of Mines, Swansea.
 J. M. RONALDSON, H.M. Inspector of Mines, 44, Athole Gardens, Glasgow.
 A. H. STOKES, H.M. Inspector of Mines, Greenhill, Derby.
 FRANK N WARDELL, H.M. Inspector of Mines, Wath-upon-Dearne, near Rotherham.

Chesterfield and Midland Counties Institution of Engineers.

- PROF. FRANK CLOWES, University College, Nottingham.
 REV. J. M. MELLO, Mapperley Vicarage, near Derby.

Midland Institute of Mining, Civil, and Mechanical Engineers.

- PROF. G. F. ARMSTRONG, The University, Edinburgh.
 JOSEPH DICKINSON, South Bank, Sandy Lane, Pendleton, Manchester.
 PROF. J. GOODMAN, Yorkshire College, Leeds.
 PROF. L. C. MIALI, Yorkshire College, Leeds.
 PROF. A. W. RUCKER, 19, Gledhow Gardens, South Kensington, London, S.W.
 PROF. R. RUSSELL, 1, Sea View, St. Bees, Carnforth.
 PROF. T. E. THORPE, The Government Laboratory, Somerset House, London, W.C.

The North of England Institute of Mining and Mechanical Engineers.

- The Right Honourable the EARL OF RAVENSWORTH, Ravensworth Castle, Gateshead-upon-Tyne.
 PROF. P. PHILLIPS BEDSON, Durham College of Science, Newcastle-upon-Tyne.
 THOMAS BELL, 15, The Valley, Scarborough.
 PROF. G. S. BRADY, Durham College of Science, Newcastle-upon-Tyne.
 DR. BRASSERT, Bonn-on-the-Rhine, Germany.
 STEPHEN CAMPBELL CRONE, Oakhurst North, Longbenton, Newcastle-upon-Tyne.
 JOS. DICKINSON, South Bank, Sandy Lane, Pendleton, Manchester.
 PROF. WILLIAM GARNETT, 75, Gunterstone Road, West Kensington, London, W.
 REV. H. P. GURNEY, Principal of the Durham College of Science, Roseworth, Gosforth, Newcastle-upon-Tyne.

WILLIAM HENRY HEDLEY, 34, Beverley Terrace, Cullercoats.
 PROF. A. S. HERSCHEL, Observatory House, Slough, Bucks.
 PROF. G. A. LEBOUR, Durham College of Science, Newcastle-upon-Tyne.
 WILLIAM LISHMAN, Thornhill Park, Sunderland.
 PROF. HENRY LOUIS, 11, Summerhill Terrace, Newcastle-upon-Tyne. *Transactions*
 to be sent to the Secretary, Durham College of Science, Newcastle-upon-Tyne.
 PROF. H. STROUD, Durham College of Science, Newcastle-upon-Tyne.

North Staffordshire Institute of Mining and Mechanical Engineers.

W. N. ATKINSON, H.M. Inspector of Mines, Barlaston, Stoke-upon-Trent.
 HUGH R. MAKEPEACE, H.M. Inspector of Mines, Newcastle, Staffordshire.
 *R. P. W. OSWALD, H.M. Inspector of Mines, 28, Lismore Terrace, Carlisle.
 HENRY SKIFFINGTON POOLE, Acadia Coal Company, Limited, Stellarton, Nova
 Scotia.
 A. R. SAWYER, P.O. Box 2233, Johannesburg, Transvaal; and 40, Brompton
 Square, London, S.W.
 C. M. STUART, St. Dunstan's College, Lewisham.

*South Staffordshire and East Worcestershire Institute of Mining
 Engineers.*

PROF. C. LAPWORTH, Mason College, Birmingham.
 PROF. R. H. SMITH, 53, Victoria Street, Westminster, London, S.W.

Members.

* Deceased.

ABRAHAM, DAVID, Pencoedcae, Merthyr Tydvil.
 ABURROW, CHARLES, P.O. Box 534, Johannesburg, Transvaal.
 ACKROYD, A., Morley Main Collieries, Leeds.
 ACKROYD, WILLIAM, Morley Main Collieries, Morley, near Leeds.
 ADAMS, DAVID, Muircambus, Colinsburgh, R.S.O., Fifeshire.
 ADAMSON, JAMES C., Victoria Place, Airdrie, N.B.
 ADAMSON, T., Kurhurbarees Colliery, E.I.R., Bengal, India.
 ADDIE, ALEXANDER, 67, Johnstone Street, Airdrie, N.B.
 ADDIE, ROBERT, Church Place, Llansamlet, Swansea.
 AGABEG, FRANK J., Apcar and Company's Collieries, Seetarampore, India.
 AGASSIZ, ALEXANDER, Museum of Comparative Zoology, Cambridge, Massachusetts,
 U.S.A.
 AINSWORTH, J. W., Bridgewater Trustees Collieries, Walkden, near Bolton,
 Lancashire.
 AITKEN, HENRY, Darroch, near Falkirk, N.B.
 ALISON, ROBERT, Greymouth Point-Elizabeth Railway and Coal Company,
 Limited, Brunnerton, New Zealand.
 ALLAN, ALEXANDER B., 7, Campside Crescent, Langside, Glasgow.
 ALLAN, C. J. G.
 ALLAN, GEORGE, Corngreaves Hall, Birmingham.
 ALLAN, JAMES, Hillhead, Coylton, Ayr, N.B.
 ALLAN, JOHN, South Cobbinshaw, Carstairs, Lanark, N.B.
 ALLAN, JOHN F., Apartado de Correo No. 121, Mexico, D.F.
 ALLAN, T. A., c/o Gibbs, Bright and Company, Melbourne, Australia.
 ALLOHURCH, ENRIQUE, Calle Las Heras, 273, Buenos Aires, Argentine Republic.

- ALLEN, REUBEN, Birch Coppice Colliery, Polesworth, near Tamworth.
 ALLISON, JOHN, 59, Waterloo Street, Glasgow.
 ALLISON, J. J. C., Woodland Collieries, Butterknowle, R.S.O., Co. Durham
 ALLSOP, SAMUEL, Marehay Collieries, Derby.
 ALSOP, A. B., Pinxton Collieries, Alfreton.
 ALSOP, A. M., Lead Mines, Darley Dale, Matlock.
 ALSOP, SAMUEL, Codnor, Derby.
 ALSTON, CHARLES F., P.O. Box 100, Pilgrims Rest, South African Republic.
 ANDERSON, CARL, P.O. Box 120, Denver, Colorado, U.S.A.
 ANDERSON, C. W., Cleadon Park, Sunderland.
 ANDERSON, GEORGE, Martin Place, Sydney, Australia.
 ANDERSON, JAMES, Farme Colliery, Rutherglen, Glasgow.
 ANDERSON, JOHN, Ellenslee, Wilson Street, Motherwell, N.B.
 ANDERSON, R. HAY, 13, San Juan de Letran, Mexico, D.F.
 ANDERSON, R. S., Elswick Colliery, Newcastle-upon-Tyne.
 ANDERSON, WALTER G., c/o Dr. Blackie, 1, Belhaven Terrace, Kelvinside, Glasgow.
 ANDREW, ROBERT, c/o John Munro, 30, George Square, Glasgow.
 ANDREWS, CHARLES FITZ-HUGH, Isaac's Harbour, Guysborough County, Nova Scotia.
 ANDREWS, THOMAS, Talk-o'-th'-Hill Colliery, Talke, Stoke-upon-Trent.
 ANDREWS, THOMAS, Wortley Iron Works, near Sheffield.
 ANGOVE, WILLIAM HENRY, Albany, Western Australia.
 ANGUS, JAMES, Radcliffe, Acklington, Northumberland.
 ANGWIN, B., P.O. Box 346, Johannesburg, Transvaal.
 ANLEY, JAMES P. B., The Avenue, Kids Grove, Stoke-upon-Trent.
 APFLEBY, W. R., 911, Fifth Street, S.E., Minneapolis, Minnesota, U.S.A.
 ARCHER, JOSEPH, Royal Insurance Buildings, Church Street, Sheffield.
 ARCHER, OAKELEY, 156, Hereford Street, Christchurch, New Zealand.
 ARCHER, T., 11, Regent Terrace, Gateshead-upon-Tyne.
 ARCHER, WILLIAM, Victoria Garesfield, Lintz Green.
 ARCHIBALD, DAVID, Dalmeny Works, Dalmeny, Linlithgowshire.
 ARGALL, CAPTAIN J., Nant-y-Mwyn Mines, Llandovery, Wales.
 ARGALL, PHILIP, P.O. Box 1095, Denver, Colorado, U.S.A.
 ARMOUR, JAMES, Clippens Oil Works, Loanhead, N.B.
 ARMSON, JESSE, Coleorton Colliery, Ashby-de-la-Zouch.
 ARMSTRONG, HENRY, Chester-le-Street.
 ARMSTRONG, LORD, C.B., LL.D., D.C.L., Craggside, Rothbury.
 ARMSTRONG, THOMAS HENRY, Blanchland House, Newcastle-upon-Tyne.
 ARMSTRONG, WILLIAM, Wingate, Co. Durham.
 ARNOLD, T., Castle Hill, Greenfields, Llanelli.
 ARNOTT, THOMAS, Fernbank, Newton, Glasgow.
 ASHCROFT, EDGAR A., The Sulphide Corporation (Ashcroft's Process), Limited, Newcastle, New South Wales.
 ASHCROFT, HARRY, Borra Coal Company, Limited, Seetarampore, Bengal, India.
 ASHMORE, G. PERCY, c/o Mrs. Ashmore, 34, Montpelier Road, Brighton.
 ASHTON, J. H., Waleswood Colliery, near Rotherham.
 ASHWIN, G. H., Charity Colliery, Bedworth, near Nuneaton.
 ASHWORTH, JOHN, 8, King Street, Manchester.
 ASHWORTH, THOMAS, 25, Regent Road, Fenton, Stoke-upon-Trent.
 ASKEW, GEORGE H., Brayton Domain Collieries, Aspatria, Cumberland.
 ASQUITH, T. W., Harperley Hall, Tantobie, R.S.O., Co. Durham

- ASTON, J., Blowers Green, Dudley, Worcestershire.
 ATHERTON, JAMES, 13, Mawdsley Street, Bolton, Lancashire.
 ATKINS, S. S., Coalbrooke Farm, Woodhouse Mill, Rotherham.
 ATKINSON, A. A., Chief Inspector of Coal Mines, c/o Hon. Minister of Mines and Agriculture, Sydney, New South Wales.
 ATKINSON, C. W., Glendale, Woodland Place, Penarth, South Wales.
 ATKINSON, FRED. R., West Street, Congleton.
 ATKINSON, J. B., H.M. Inspector of Mines, 10, Foremount Terrace, Glasgow.
 ATKINSON, J. W., Sterndale Road, Millhouses, Sheffield.
 ATKINSON, L. B., 10, Westbourne Road, Penarth, South Wales.
 ATKINSON, R. HUGH M. BUDDLE, c/o Dees and Thompson, Pilgrim Street, Newcastle-upon-Tyne.
 ATKINSON, T. D., Hearn House, Chesterfield.
 ATKINSON, W. N., H.M. Inspector of Mines, Barlaston, Stoke-upon-Trent.
 ATTERBURY, BASIL J., 141, Copthall House, Copthall Avenue, London, E.C.
 AUBREY, R. C.
 AUSTIN, W. LAWRENCE, P.O. Box 941, Denver, Colorado, U.S.A.
 AYTON, ERNEST F., El Bote Mining Negociacion, Zacatecas, Republic of Mexico.
 AYTON, HENRY, 122, Rye Hill, Newcastle-upon-Tyne.
- BACKHOUSE, FRANK HERBERT, West Australian Gold-fields, Limited, Coolgardie, Western Australia.
 BAILES, E. T., Wingate, Ferryhill.
 BAILES, G. M., Hinckley Road, Nuneaton.
 BAILES, T., Jesmond Gardens, Newcastle-upon-Tyne.
 BAILEY, E. J., 30, Waterloo Street, Birmingham.
 BAILEY, EDWARD TRENHOLM, Mining Engineer, Sandakan, British North Borneo.
 BAILEY, SAMUEL, 30, Waterloo Street, Birmingham.
 BAILEY, S. and J., 30, Waterloo Street, Birmingham.
 BAIN, JAMES, 4, Gardenside Terrace, Uddingston, N.B.
 BAINBRIDGE, EMERSON, 4, Whitehall Court, London, S.W.
 BAIRD, ARCHIBALD, Park Road, Hamilton, N.B.
 BAIRD, DUGALD, Radcliffe Colliery, Acklington, Northumberland.
 BAIRD, JAMES, Auchincruive Coal Company, Prestwick, R.S.O., Ayrshire.
 BAIRD, MATTHEW B., Hillside, Hamilton, N.B.
 BAIRD, ROBERT, 46, Gordon Street, Glasgow.
 BALFOUR, J. L., Day Dawn, Western Australia.
 BALLARD, R., Menzies, Western Australia.
 BALLINGAL, NEIL, Sweet Bank, Markinch, N.B.
 BANCROFT, ROBERT E., 8, St. James' Square, Manchester.
 BANHAM, E. G., Barrow Collieries, Barnsley.
 BANKS, THOMAS, 29, The Park, Eccles, near Manchester.
 BANNISTER, DAVID, Shawcross, near Dewsbury.
 BARBER, WILLIAM, Great Fenton Collieries, Stoke-upon-Trent.
 BARKER, M. W., P.O. Box 1463, Johannesburg, Transvaal.
 BARLOW, J. W., Bold Hall, St. Helen's, Lancashire.
 BARNARD, A. H., Russell Cottage, Cannock, Staffordshire.
 BARNES, ALFRED, Ashgate Lodge, Chesterfield.
 BARNES, A. G., Tupton Hall, Claycross, Chesterfield.
 BARNES, A. T. H., Grassmoor Collieries, Chesterfield.
 BARR, WILLIAM, Machanhill House, Larkhall, R.S.O., Lanarkshire.
 BARRACLOUGH, JAMES, 29, Raglan Street, Halifax.

- BARRACLOUGH, SAMUEL, Union Foundry, Barnsley.
 BARRETT, C. R., Whitehill Hall, Chester-le-Street.
 BARRON, THOMAS, Rylands Main Colliery, Barnsley.
 BARBOWMAN, JAMES, Staneacre, Hamilton, N.B.
 BARWELL, W. H., Fence Cottage, Woodhouse Mill, Rotherham.
 BATEMAN, JAMES T., Fair View, Bebington, near Birkenhead.
 BATES, SIDNEY, Mickley Colliery Offices, Stocksfield-upon-Tyne.
 BATES, THOMAS, The Grange, Prudhoe-upon-Tyne.
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 BATEY, JOHN, Newbury Collieries, Coleford, Bath.
 BATTY, W., Darley Grove, Worsbro' Dale, Barnsley.
 BAUMGARTNER, W. O., Whitburn, near Sunderland.
 BAYLDON, DANIEL HENRY, c/o New Zealand Mines Trust, Limited, Auckland,
 New Zealand.
 BEACHER, A. L., Hemingfield, Barnsley.
 BEANLANDS, ARTHUR, Palace Green, Durham.
 BEARD, A., Carlton Villa, Carlton, near Barnsley.
 BECHER, SEPTIMUS J., Geological Survey Office, Perth, Western Australia.
 BECH, NOEL TENCH, Lilleshall Collieries, St. George's, Wellington, Salop.
 BEHRENS, HERR BERGRATH, Hibernia Company, Herne, Westphalia.
 BEITH, ROBERT, Lassodie Mill Colliery, Blairadam, Fifeshire.
 BELFITT, WILLIAM, Brethby Colliery, Burton-upon-Trent.
 BELL, ALAN D., Bonne Terre, St. Francois County, Missouri, U.S.A.
 BELL, GEORGE FRED, H. M. Inspector of Mines, 30, Eldon Street, Newcastle-
 upon-Tyne.
 BELL, JAMES, The Lührig Appliances, Limited, 32, Victoria Street, London, S. W.
 BELL, SIR LOWTHIAN, Bart., Rounton Grange, Northallerton.
 BELL, R. G., 42, Burdon Terrace, Newcastle-upon-Tyne.
 BELL, WALTER, c/o Pyman, Bell and Company, Hull.
 BELLINGHAM, GEORGE, Bayley Street, Coolgardie, Western Australia.
 BENN, E. S., 36, Peel Street, Morley, Leeds.
 BENNETT, ALFRED H., Dean Lane Collieries, Bedminster, Bristol.
 BENNETT, JOHN, Langwith Colliery, near Mansfield.
 BENNETT, J. T., Silkstone and Haigh Moor Collieries, Allerton Bywater, Castle-
 ford.
 BENSON, JAMES R., West Longrigg, Airdrie, N.B.
 BENSON, J. G., 12, Grey Street, Newcastle-upon-Tyne.
 BENSON, T. W., 24, Grey Street, Newcastle-upon-Tyne.
 BENSON, W. A., Silverdale, Staffordshire.
 BERINGER, R. E., Highway, Illogan, Redruth, Cornwall.
 BERKLEY, C., Marley Hill, Swalwell, R.S.O., Co. Durham.
 BERKLEY, FREDERICK, Hamsterley Colliery, Ebchester, R.S.O., Co. Durham.
 BERKLEY, R. W., Marley Hill, Swalwell, R.S.O., Co. Durham.
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 BEVERIDGE, JAMES, Linlithgow Oil Company, Linlithgow, N.B.
 *BEWICK, T. J., Broad Street House, Old Broad Street, London, E.C.
 BEYNON, J. C. S., P.O. Box 1364, Johannesburg, Transvaal.
 BIBBY, WILLIAM, The Raub Australian Gold Mining Company, Limited, Raub,
 Pahang, Malay Peninsula.
 BIGG-WITHER, H., 10, Swinley Road, Wigan, Lancashire.
 BIGLAND, J., Henknowle, Bishop Auckland.

- BILGRAMI, SYED ALI SHAMSUL ULAMA, Director General of Mines, Hyderabad, Deccan, India.
- BINNS, G. J., Netherseal Colliery, Burton-upon-Trent.
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- BISHOP, GEORGE A., Gartverrie Fireclay Works, Glenboig, Coatbridge, N.B.
- BISHOP, JAMES, Grey Valley Coal Company, Brunnerton, Greymouth, New Zealand.
- BLACK, DONALD, 136, Almada Street, Hamilton, N.B.
- BLACK, W., Lovaine House, Lovaine Place, Newcastle-upon-Tyne.
- BLACKADDER, ALEXANDER, Stand Colliery, Airdrie, N.B.
- BLACKBURN, W. STEVENSON, Aive Villas, Astley, Woodlesford, near Leeds.
- BLACKETT, W. C., Acorn Close, Sacriston, Durham.
- BLACKWOOD, JAMES, Scott Street, Hamilton, N.B.
- BLAKELEY, A. B., Soothill Wood Colliery, Batley.
- BLAKEMORE, W., Dominion Coal Company, Limited, Glace Bay, Cape Breton, Canada.
- BLANE, JAMES, P.O. Box 435, Johannesburg, Transvaal.
- BLANE, ROBERT, P.O. Box 435, Johannesburg, Transvaal.
- BLANE, W., P.O. Box 435, Johannesburg, Transvaal.
- BLYTH, ARCHIBALD, Park Road, Hamilton, N.B.
- BOAM, S. T., Whitwick Colliery, Coalville, Leicestershire.
- BOLAM, PHILIP, North Walbottle Colliery, Newcastle-upon-Tyne.
- BOLTON, EDGAR ORMEROD, Executor of Colonel Hargreaves, Colliery Offices, Burnley.
- BOLTON, H. H., Newchurch Collieries, near Manchester.
- BONSER, HAROLD, 39, Hanover Square, Leeds.
- BONTHORNE, BARCLAY, Newton House, Falklands, Fife.
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- BOOLE, GEORGE, The Lodge, Rainford, near St. Helen's, Lancashire.
- BORLASE, W. H., Brown How, Ulleswater, Glenridding, near Penrith.
- BORROWMAN, JAMES, Armadale Station, Linlithgowshire.
- BOTT, SAMUEL J., The Villas, Stoke-upon-Trent.
- BOUCHER, A. S., Kempsey House, near Worcester.
- BOULDEN, F., Technical Department, University College, Sheffield.
- BOULTON, WILLIAM, Burslem, Stoke-upon-Trent.
- BOWEN, J., Cleveland House, Wellington Road, Bilston.
- BOWIE, HUNTER, Lugar Iron Works, Old Cumnock, N.B.
- BOWIE, KENNETH McK., Priory Hill House, Canonbie, N.B.
- BOWIE, W. T., 90, Dobbie's Loan, Glasgow.
- BOWMAN, ARCHIBALD, Jun., Percival Cottage, Buckhaven, Fife.
- BOYD, ADAM A., Newcastle Wallsend Coal Company, Wallsend, New South Wales.
- BRADFORD, GEORGE, Norton Palms, Darlington.
- BRAGGE, G. S., Granville Colliery, Swadlincote, Burton-upon-Trent.
- BRAIN, F., Trafalgar House, Drybrook, Gloucester.
- BRAMLEY, GEORGE, Clay Cross Works, Chesterfield.
- BRAMWELL, HUGH, Great Western Colliery, near Pontypridd, Glamorganshire.
- BRANCKER, RICHARD, The Pearson and Knowles Coal and Iron Company, Limited, 11, Old Hall Street, Liverpool.
- BRAND, MARK, Barchill Cottage, Twechar, Kilsyth, Glasgow.
- BREACKELL, JOHN E.
- BREACKELL, THOMAS, Brassington, near Derby.
- BRECKON, J. R., 53, John Street, Sunderland.

- BREWIS, GEORGE, Boythorpe Colliery, Chesterfield.
- *BRIDGETT, WILLIAM, Berry Hill Collieries, Stoke-upon-Trent.
- BRIERLEY, BRANDON TALFOURD, 10, Marsden Street, Manchester.
- BRIERLEY, W., Carlinghow Colliery Company, Carlinghow Lane, Batley.
- BRITTEN, T. J., P.O. Box 494, Johannesburg, Transvaal.
- BRITTON, ARTHUR, The Lathams, Whiston, near Prescott.
- BROJA, RICHARD, 77, Kaiser-Wilhelmstrasse, Breslau, Germany.
- BROMLY, A. H., 29, Billiter Square Buildings, London, E.C. Transactions to be sent to c/o Thomas Hammond, Stanwell Street, Colchester, Sussex.
- BROOKE, ED., Edgerton, near Huddersfield.
- BROOM, ROBERT, Kirkwood Colliery, Bargeddie, N.B.
- BROUGH, BENNETT H., c/o Iron and Steel Institute, 28, Victoria Street, London, S. W.
- BROUGH, THOMAS, New Seaham Colliery, Sunderland.
- BROUGHALL, J., Bushbury View, Prestwood Road, Wolverhampton.
- BROWN, ADAM, Allanton Colliery, Hamilton, N.B.
- BROWN, A. T., 372, Flinders Lane, Melbourne, Australia.
- BROWN, E., St. John's Colliery, Normanton.
- BROWN, GEORGE, Longriggend Colliery, Airdrie, N.B.
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- BROWN, M. WALTON, 10, Lambton Road, Newcastle-upon-Tyne.
- BROWN, THOMAS, Westport Coal Company, Millerton, Westport, New Zealand.
- BROWN, THOMAS FORSTER, Guildhall Chambers, Cardiff.
- BROWN, THOMAS M., Lanemark Colliery, New Cumnock, R.S.O., Ayrshire.
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- BROWNE, R. J., Barakar, East India Railway, Bengal, India.
- BRUCE, JOHN, Port Mulgrave, Hinderwell, R.S.O., Yorkshire.
- BRUNT, JAMES, Park Road, Fenton, Stoke-upon-Trent.
- BRUNTON, THOMAS, Gray Street, Shotts, N.B.
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- BUGLASS, JOHN, Stobswood, *via* Acklington, Northumberland.
- BULKLEY, F. G., Denver, Colorado, U.S.A.
- BULLOCK, J.
- BULMAN, E. H., North Randfontein Gold Mining Company, Limited, Mine Office, Krugersdorp, South African Republic.
- BULMAN, H. F., Roeville, Richmond Hill Avenue, Clifton, Bristol.
- BUNKELL, H. B., P.O. Box 1463, Johannesburg, Transvaal.
- BUNNING, C. Z., c/o The Borax Company, Limited, 2, Macri Khan, Constantinople.
- BUNTINE, HUGH P., Transy, Dunfermline, N.B.
- BURGESS, JAMES, Burnfoot, Patna, Ayr, N.B.
- BURGIN, HENRY, 28, Stead Street, Eckington, Sheffield.
- BURLS, HERBERT T., Southdene, Sydenham, London, S.E.
- BURN, FRANK H., 22, Windsor Terrace, Newcastle-upon-Tyne.
- *BURN, JAMES, 28, Fawcett Street, Sunderland.
- BURNETT, CUTHBERT, Fallowfield House, South Hetton.
- BURNS, DAVID, Scotland Road, Stanwix, Carlisle.
- BURNS, JAMES, 10, Balmoral Crescent, Glasgow.

BURROWS, J. S., Green Hall, Atherton, near Manchester.
 BURT, HUTCHISON, Dechmont Colliery, Newton, Glasgow.
 BUSH, JAMES, P.O. Box 10, Eikeboom, Middelburg, South African Republic.
 BUTTERLEY, WILFRED, Fountain and Burnley's Thorp's Gawber Collieries, Darton, Barnsley.
 BUTTERS, CHARLES, P.O. Box 1891, Johannesburg, Transvaal.
 BYRNE, JNO. WALTER, 16, King Street, Tunstall, Staffordshire.

CADELL, H. M., Grange, Bo'ness, R.S.O., Linlithgowshire.
 CADMAN, JAMES C., Silverdale Collieries, Newcastle, Staffordshire.
 CAINCROSS, JOHN M., Langloan Iron Works, Coatbridge, N.B.
 CALDERWOOD, ROBERT, 97, Campbell Street, Dunfermline, N.B.
 CALDWELL, HUGH, Oak House, Blackwood, near Newport, Monmouthshire.
 CALDWELL, JAMES, Pumpherton, Mid-Calder, N.B.
 CAMERON, IAN, Sudbury, Ontario, Canada.
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 CAMPBELL, H. H., Sutton Hall, St. Helen's, Lancashire.
 CAMPBELL, Rev. JOSEPH, Te Aroha, New Zealand.
 CAMPBELL, W. YOUNG, P.O. Box 357, Johannesburg, Transvaal.
 CAMPBELL-JOHNSTON, R. C., P.O. Box 40, Vancouver, British Columbia.
 CANDLER, T. E., East Lodge, Crook, Co. Durham.
 CARLOW, CHARLES, The Fife Coal Company, Leven, Fife.
 CARNES, CHARLES SPEARMAN, Cornwall House, Murton Colliery, Sunderland.
 CARE, THOMAS, Lilywhite Terrace, Four Lane Ends, Hetton-le-Hole, R.S.O., Co. Durham.
 CARBALL, J. W., Commissioner of Customs, Chefoo, China.
 CARRINGTON, ARTHUR, Langdale House, Clapham Road, Bedford.
 CARRINGTON, THOMAS LIONEL SHAW, Midland Chambers, York Street, Sheffield.
 CAZALET, L. P., P.O. Box 348, Johannesburg, Transvaal.
 CHALLINOR, CHARLES E., Shallowford House, near Stone, Staffordshire.
 CHALMERS, GEORGE, Superintendent of the St. John del Rey Mining Company, Finsbury House, Blomfield Street, London, E.C.
 CHAMBERS, ALFRED, Eastwood, Notts.
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 CHAMBERS, J. S., Osnaburgh House, Regent's Park, London.
 CHAMBERS, WILLIAM HENRY, Conisborough, Rotherham.
 *CHAMBERS, W. HOOLE, Milton House, Hoyland, Barnsley.
 CHANDLER, N., Hednesford, Staffordshire.
 CHANDLEY, CHARLES, P.O. Box 221, Coolgardie, Western Australia.
 CHANNING, J. PARKE, 34, Park Place, New York City, U.S.A.
 CHAPMAN, H. R., Victoria Works, Gateshead-upon-Tyne.
 CHAPMAN, W. H., Alma House, Colley Gate, Cradley, Staffordshire.
 CHARLETON, A. G., 5, Avonmore Road, Kensington, London, W.
 CHARLTON, W., Linares, Provincia de Jaen, Spain.
 CHARLTON, WILLIAM, Alpine Villas, Bloxwich Road, Walsall.

- CHARLTON, WILLIAM JOHN, Ashington Colliery, Morpeth, Northumberland.
 CHATER, JOSEPH, Bengal Nagpur Coal Company, Limited, Evelyn Lodge, Kumarpur, Asansol, Bengal, India.
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 CHEESMAN, L. T., Throckley Colliery, Newcastle-upon-Tyne.
 CHEESMAN, W. T., Hartlepool.
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 CHICKEN, LANCELOT W.
 CHILDE, HENRY S., Wakefield.
 CHRYSTLE, THOMAS, Longton Hall Colliery, Longton, Staffordshire.
 CHURTON, T. H., 36, Great Wilson Street, Leeds.
 CLARK, CHARLES, Church Lane, Tipton, Staffordshire.
 CLARK, C. F., Garswood Coal and Iron Company, Limited, near Wigan.
 CLARK, GEORGE, Newton-in-the-Willows, Lancashire.
 CLARK, JAMES, Melville Villas, Eskbank, Mid Lothian.
 CLARK, JOHN, Dunnikeir Colliery, Kirkcaldy, N.B.
 CLARK, JOHN, 3A, North St. David Street, Edinburgh.
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 CLARK, R. B., Springwell Colliery, Gateshead-upon-Tyne.
 CLARK, WILLIAM, 203, St. Vincent Street, Glasgow.
 CLARK, W. F., The Poplars, Aldridge, near Walsall.
 CLARKE, E. B., 38, Norfolk Street, Sheffield.
 CLARKE, JAMES A., Ayr Colliery, Annbank, R.S.O., Ayrshire.
 CLARKE, T. B. A., Lidgett Colliery, Tankersley, Barnsley.
 CLAUDET, ARTHUR C., 6 and 7, Coleman Street, London, E.C.
 CLAUGHTON, G. H., The Priory, Dudley, Worcestershire.
 CLAYTON, C. D., Doncaster.
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 CLKILLAND, JAMES, Carronhall Colliery, Falkirk, N.B.
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 CLIFFORD, WILLIAM, Pittsburg, Pennsylvania, U.S.A.
 CLIVE, ROBERT C., Clanway Colliery, Tunstall, Staffordshire.
 CLOUGH, JAMES, Bomarsund House, Bomarsund, Bedlington, R.S.O.
 CLOUGH, S., Micklefield Colliery, Leeds.
 COATS, WILLIAM A., Skelmorlie Castle, Skelmorlie, R.S.O., Ayrshire.
 COBBOLD, C. H., Wentworth Castle, Barnsley.
 COCHRANE, B., Aldin Grange, Durham.
 COCHRANE, C., Green Royde, Pedmore, near Stourbridge.
 COCHRANE, WILLIAM, St. John's Chambers, Grainger Street West, Newcastle-upon-Tyne.
 COCKIN, GEORGE M., Heron Street, Rugeley, Staffordshire.
 COCKIN, T. H., Tinsley Park Colliery, Sheffield.
 COCKSON, CHARLES, Wingates, Hayes, Middlesex.
 COGHLAN, F. M., Catoree, S.L.P., Mexico.
 COHEN, E. H. A., P.O. Box 168, Barberton, Transvaal, South Africa.
 COKE, G. E., 65, Station Street, Nottingham.
 COLE, JOHN H., Knypersley, Biddulph, near Congleton.

- COLE, ROBERT HEATH, Endon, Stoke-upon-Trent.
COLLINS, ARTHUR LAUNCELOT, 14 and 15, Broad Street Avenue, London, E.C.
COLLINS, HORATIO, General Manager, Modderfontein Extensions, Limited,
P.O. Box 735, Johannesburg, Transvaal.
COLLINS, H. B., 121, West George Street, Glasgow.
COLLIS, W. B., Stourbridge, Worcestershire.
COLQUHOUN, JAMES, 22, Airdrie Hill Street, Rawyards, Airdrie, N.B.
COLQUHOUN, T. GRANT, General Manager, Cassell Coal Company, Limited,
Springs, South African Republic.
COMMANS, R. E., 6, Queen Street Place, London, E.C.
COMSTOCK, THEO. B., Prescott Development Syndicate, Limited, 535, Stimson
Block, Los Angeles, California, U.S.A.
COOK, J., Washington Iron Works, Washington, Co. Durham.
COOK, J. W., Teasdale House, Princes Street, Bishop Auckland.
COOKE, HENRY MOORE ANNESLEY, The Pestarena United Gold Mining Company,
Limited, Pestarena, Vall Anzasca, Novara, Italy.
COOKSEY, J. H., Lombard Street, West Bromwich.
CORBETT, V. W., Chilton Moor, Fence Houses.
CORBOULD, W. H., P.O. Box 796, Rossland, British Columbia, *via* New York.
CORK, F. LAWRENCE.
CORLETT, G. S., Wigan.
COTTERELL, O. J., 16, Bank Street, Sheffield.
COULSON, FRANK, 10, Victoria Terrace, Durham.
COULTAS, FRED., Deepcar, near Sheffield.
COULTHARD, FRANCIS, Arica Villa, Whitehaven.
COWAN, JAMES, Cadzow Colliery, Hamilton, N.B.
COWIE, ARCHIBALD D., Alma Vale, Airdrie, N.B.
COWLISHAW, W. G., Etruria, Stoke-upon-Trent.
COX, J. H., 10, St. George's Square, Sunderland.
COX, S. HERBERT, 13, St. Helen's Place, London, E.C.
CRADOCK, GEORGE, Rope Works, Wakefield.
CRAIG, W. Y., Milton House, Alsager, Cheshire.
CRAVEN, HIRAM, Jun., Mechanical Engineer, Sunderland.
CRAVEN, JOHN, Albion Villas, Alverthorpe Road, Wakefield.
CRAVEN, JOHN WILLIAM, Westgate Common Foundry, Wakefield.
CRAWSHAW, C. B., The Collieries, Dewsbury.
CREMER, RICHARD, 25, Cookridge Street, Leeds.
CRESWICK, A. J., Gatefield, Sheffield.
CRESWICK, W., Sharlestone Colliery, Normanton.
CRICHTON, A. H., Castlepark, Linlithgow, N.B.
CRIGHTON, HUGH, Bute House, Airdrie, N.B.
CRIGHTON, JOHN, Union Iron Works, Stewart Street, Stockport.
CROFT, HENRY, Kaslo, British Columbia.
CROMPTON, GEORGE, Stanton Hall, Nottingham.
CRONE, E. W., Killingworth, near Newcastle-upon-Tyne.
CRONE, J. R., Tudhoe House, *via* Spennymoor.
CROOKSTON, ANDREW, Wemyss Colliery, East Wemyss, R.S.O., Fife.
CROOKSTON, A. W., 19, Wellington Street, Glasgow.
CROSBY, GEORGE, Croft House, Featherstone, Pontefract.
CROSS, JOHN, 77, King Street, Manchester.
CROSSLAND, A., Middleton, Leeds.
CROUDACE, C. J., Bettisfield Colliery Company, Limited, Bagillt, North Wales

CRLOUDACE, FRANK, The Scottish Australian Mining Company, Limited,
Lambton, Newcastle, New South Wales.

CRLOUDACE, T., West House, Haltwhistle.

CRLOUDACE, THOMAS, Lambton Lodge, Lambton, Newcastle, New South Wales.

CURRIE, WALTER, P.O. Box 220, Bulawayo, Rhodesia, South Africa.

CURRY, W. THOMAS, Wentwood, near Caerleon, Monmouthshire.

CUTHBERTSON, JOHN, Thomson Street, Kilmarnock, N.B.

*DACRES, THOMAS, Reitz Street, Kimberley, South Africa.

DAGLISH, JOHN, Rothley Lake, Cambo, R.S.O., Northumberland.

DALGLISH, WILLIAM CHARLTON, Rodridge House, Hutton Henry Colliery,
Wingate, R.S.O., Co. Durham.

DARKERS, W. R., The Loggins, Tudhoe Colliery, via Spennymoor.

DALE, Sir DAVID, Bart., West Lodge, Darlington.

DALZELL, JOHN B., Larkhall, N.B.

DAN, TAKUMA, c/o Mitsui Mining Company, No. 4, Surugacho, Nihonbashi-
Ku, Tokio, Japan.

DANIEL, P. F., Greymouth, New Zealand.

DANKS, ANDREW.

DARBY, JOHN H., Brymbo, near Wrexham.

DARLING, FENWICK, South Durham Colliery, Darlington.

DARLINGTON, JAMES, Black Park Colliery, Ruabon, North Wales.

DAVEY, GEORGE, Waitekauri Gold Mining Company, Waitekauri, Auckland,
New Zealand.

DAVEY, HENRY, 3, Princes Street, Westminster, London, S.W.

DAVIES, ALFRED, Engineering Works, Burton-upon-Trent.

DAVIES, Lt.-Colonel JASPER G. S., Marton, Middlesbrough.

DAVIES, JOHN, Hartley House, Coundon, Bishop Auckland.

DAVIES, J. HUBERT, P.O. Box 455, Johannesburg, Transvaal.

DAVIES, MORGAN W., 3, Gloucester Place, Swansea.

DAVIES, T. J., Balls Hill, West Bromwich.

DAVIS, HENRY, All Saints Works, Derby.

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DAVISON, J. FORD, Yarlside, Dalton-in-Furness.

DAW, JOHN, Jun., Brooklands, Rosemont Road, Acton, London, W.

DAWBARN, A. G., 60, Gracechurch Street, London, E.C.

DAWSON-CROSBIE, G. J., May Place, Newcastle-under-Lyme, Staffordshire.

DEACON, MAURICE, Whittington House, near Chesterfield.

DEAN, ARTHUR, Waterloo Road, Burslem, Stoke-upon-Trent.

DEAN, WILLIAM, The Pearson and Knowles Coal and Iron Company, Limited,
Wigan.

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DEES, J. GIBSON, Floraville, Whitehaven.

DEES, R. R., Newcastle-upon-Tyne.

DELPRAT, G. D., c/o Delprat and Carr, 3, Great Winchester Street, London, E.C.

DENNY, G. A., African City Properties Trust Buildings, Room 26, Market Street,
Johannesburg, Transvaal.

DEVONSHIRE, THE DUKE OF, K.G., Chatsworth, Baslow, Derbyshire.

DEWAR, THOMAS, Clydesdale Collieries, Springs, Johannesburg, Transvaal.

DEWHURST, Captain HAROLD, The East India United Service Club, London, S. W.

DICKENSON, CHARLES, Hickleton Main Colliery, Thurnscoe, Rotherham.

DICKINSON, ARTHUR, Warham Road, South Croydon, Surrey.

- DICKINSON, GEORGE W., Eckington Collieries, Sheffield.
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 DIXON, WALTER, 164, St. Vincent Street, Glasgow.
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 DOBBS, JOSEPH, Jarrow Colliery, Castlecomer, Co. Kilkenny.
 DOBINSON, LANCELOT, Victoria Coal Company, Park Hills Colliery, Wakefield.
 DODD, B., Bearpark Colliery, near Durham.
 DODD, M., Burncroft, Hexham.
 DODD, T. R., P.O. Box 317, Johannesburg, Transvaal.
 DONALD, A. W., 5, West Regent Street, Glasgow.
 DONALD, J. MACINTOSH, Bantjes Consolidated Mines, Limited, Florida, South African Republic.
 DONALDSON, ROBERT, Clyde Iron Works, Tollcross, Glasgow.
 DONKIN, W., Witbank Colliery, per Special Post Bag, via Pretoria, South Africa.
 DOUGLAS, A. S., Hucknall Torkard, Nottingham.
 DOUGLAS, C. P., Thornbeck Hill, Carmel Road, Darlington.
 DOUGLAS, JOHN, 4, Brandling Terrace, Felling, R.S.O., Co. Durham.
 DOUGLAS, M. H., Usworth Colliery, Washington, R.S.O., Co. Durham.
 DOUGLAS, THOMAS, The Garth, Darlington.
 DOWDESWELL, H., Butterknowle Colliery, via Darlington.
 DOYLE, PATRICK, *Indian Engineering*, 19, Lall Bazaar, Calcutta, India.
 DRINNAN, WALTER, Waverley Coal Company, Darnall, Sheffield.
 DRON, R. W., 79, West Regent Street, Glasgow.
 DUDLEY, URIAH, The White Rock Silver Mine, Limited, Drake, New South Wales.
 DUMAT, ALFRED, 1, Loop Street, Pietermaritzburg, Natal.
 DUNDAS, EDMUND, Union Gold Mining Company, Limited, Barberton, Transvaal.
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 DUNLOP, COLIN JOHN, Quarter Collieries, Hamilton, N.B.
 DUNN, DAVID G., Coilsholm, Cambuslang, Glasgow.
 DUNN, ROBERT, 168, Kenmuir Street, Pollokshields, Glasgow.
 DUNN, WILLIAM L., 183, West George Street, Glasgow.
 DUNSIRE, ANDREW, 66, Main Street, Lochgelly, R.S.O., Fifeshire.
 DURNFORD, H. ST. JOHN, Ackton Hall Colliery, Featherstone, near Pontefract.
 DUTSON, JOHN, Orgreave Colliery, near Sheffield.
 DYSON, JOHN S., Kirkburton, Huddersfield.
 DYSON, T. I., Mount Morgan, via Rockhampton, Queensland.
 EAGLE, GEORGE, c/o Cross and Eagle, 77, King Street, Manchester.
 EARDLEY, EDWIN, 7, Wilson Street, Derby.
 EARDLEY, J. W., The Grove, Alfreton.
 EASTLAKE, A. W., Balham, London.
 EASTWOOD, EDWARD, Railway Wagon Works, Chesterfield.
 EASTWOOD, G. A., Tipton Villa, Chesterfield.
 EDE, FRANCIS J., Silchar, Cachar, India.
 EDE, HENRY EDWARD, c/o New Explosives Company, Stowmarket, Suffolk.

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 EDWARDS, EDWARD, Maindy Pit, Ocean Collieries, Ton Pentre, Glamorganshire.
 EDWARDS, TELFORD, Tati, Matabeleland.
 EISSLER, M., 5, Post Office Chambers, Sydney, New South Wales.
 EKBERG, B. P., Doveton Street, North Ballarat, Victoria, Australia.
 ELCK, GEORGE, Clayton-le-Moors, Accrington, Lancashire.
 ELCE, JAMES, Hoyland Silkstone Colliery, Hoyland, near Barnsley.
 ELEY, J. J., Snyderdale Collieries, near Pontefract.
 ELLIOTT, WILLIAM, Blackwell Collieries, Alfreton.
 ELLIS, W. R., Wigan.
 ELLISON, C. C., Monckton Main Colliery, Barnsley.
 ELSDON, ROBERT, "Esperanza," 381, Hagley Road, Edgbaston, Birmingham.
 ELWEN, THOMAS LEE, Littleburn Colliery, near Durham.
 EMBLETON, H. C., Central Bank Chambers, Leeds.
 EMBLETON, T. W., The Cedars, Methley, Leeds.
 EMINSON, J. B., Londonderry Offices, Seaham Harbour.
 EPTON, W. MARTIN, P.O. Box 737, Johannesburg, Transvaal.
 ETHERINGTON, J., 39A, King William Street, London Bridge, London, E.C.
 EVANS, D. L., 5, Bute Crescent, Cardiff.
 EVANS, LEWIS, P.O. Box 2691, Johannesburg, Transvaal.
 EVERARD, J. B., 6, Millstone Lane, Leicester.
 EVERSON, CHARLES, Sheepbridge Colliery Offices, near Chesterfield.

 FAIRLEY, JAMES, Craghead and Holmside Collieries, Chester-le-Street.
 FALLOWS, WILLIAM, Arbury Road, Nuneaton.
 FARMER, A., Seaton Carew, near West Hartlepool.
 FAULDS, ALEXANDER, Steel Works, Calderbank, N.B.
 FAVELL, THOMAS MILNES, Heatherlea, Wolstanton, Stoke-upon-Trent.
 FEARN, J. W., Devonshire Street, Chesterfield.
 FELLOWS, ALFRED, The Bede Metal and Chemical Company, Limited, Hebburn,
 Newcastle-upon-Tyne.
 FENN, ABRAHAM, Tame Valley Colliery, Wilnecote, Tamworth.
 FENNELL, CHARLES W., 17, Wood Street, Wakefield.
 FENWICK, BARNABAS, 84, Osborne Road, Newcastle-upon-Tyne.
 FENWICK, P. J., The Sutton Colliery Company, Limited, Sutton-in-Ashfield,
 Notts.
 FENWICK, T. E., Mayfield, Wolsingham, near Darlington.
 FERENS, F. J., Silksworth Colliery, Sunderland.
 FERENS, F. S., 13, Railway Arches, Westgate Road, Newcastle-upon-Tyne.
 FERGIE, CHARLES, Drummond Colliery, Westville, Nova Scotia.
 FERGUSON, D., c/o James Ferguson, 115, Buccleuch Street, Garnethill, Glasgow.
 FERGUSON, JAMES, P.O. Box 253, Johannesburg, Transvaal.
 FERGUSON, PETER, 19, Royal Exchange Square, Glasgow.
 FIELD, J., Hill Top, West Bromwich.
 FIGARI, ALBERTO, Apartado No. 255, Lima, Peru.
 FINDLAY, G. J., Broughton and Plas Power Collieries, near Wrexham.
 FISHER, E. R., Nant Glas, Cross Hands, near Llanelly, South Wales.
 FISHER, HENRY, Clifton Colliery, Nottingham.
 FISHER, ROBERT, 9, Regent Park Terrace, Strathbungo, Glasgow.
 FISHER, THOMAS T., Lichfield Chambers, Walsall.

- FISHWICK, R., Binchester Colliery, Co. Durham.
 FITTON, GEORGE, Highfield House, Beeston, near Leeds.
 FLEMING, C. E., 71, Elswick Road, Newcastle-upon-Tyne.
 FLEMING, DAVID.
 FLEMING, JOHN, P.O. Box 1878, Johannesburg, Transvaal.
 FLETCHER, JAMES, Wickham and Bullock Island Coal Company, Limited, Carrington, New South Wales.
 FLETCHER, LANCELOT, Brigham Hall, Carlisle.
 FLETCHER, WALTER, The Hollins, Bolton, Lancashire.
 FLINT, JOHN, Broomhill Colliery, Acklington, Northumberland.
 FOGGIN, W., 12, Devonshire Place, Jesmond, Newcastle-upon-Tyne.
 FOGGO, W., The Glen, Brereton, Rugeley.
 FOOTE, ARTHUR DE WINTÉ, P.O. Box 491, Grass Valley, California, U.S.A.
 FORBES, ALEXANDER, Glebe Street, Bellshill, N.B.
 FORBES, ALEXANDER, 4, Killoch Place, Ayr, N.B.
 FORD, C. F. V., Marehay Main Colliery, Ripley, Derby.
 FORD, JAMES, Hotel Street, Coalville, near Leicester.
 FORD, MARK, Sherburn Colliery, near Durham.
 FORD, STANLEY H., P.O. Box 2056, Johannesburg, Transvaal.
 FORGIE, JAMES T., Bothwell Collieries, Bothwell, Glasgow.
 FORREST, J. C., Holly Bank Colliery, Essington, Wolverhampton.
 FORRESTER, H. C., Clydesdale Collieries, Springs, Johannesburg, Transvaal.
 FORRESTER, ROBERT, Salt Lake City, Utah, U.S.A.
 FORSTER, G. B., Farnley Hill, Corbridge-upon-Tyne.
 FORSTER, J. R., Water Company's Office, Newcastle-upon-Tyne.
 FORSTER, T. E., 3, Eldon Square, Newcastle-upon-Tyne.
 FORSYTH, JAMES, Parkfoot, Falkirk, N.B.
 FORSYTH, WILLIAM, Glenclelland House, Wishaw, N.B.
 FOSTER, GEORGE, Lyme House, Rotherham.
 FOSTER, GEORGE, Osmondthorpe Colliery, Leeds.
 FOULSTONE, W., Coach and Horses Hotel, Barnsley.
 FOWLER, GEORGE, Basford Hall, Nottingham.
 FOWLER, R., Washington Colliery, Washington Station, R.S.O., Co. Durham.
 FOWLER, THOMAS, Senior Inspector of Mines, Coolgardie, Western Australia.
 FOWLER, W. C., Beeston, Notts.
 FOX, SAMSON, Grove House, Harrogate.
 FRECHEVILLE, WILLIAM, Claremont, Nutfield, Redhill, Surrey.
 FRENCH, JOHN, Millcroft Cottage, Rutherglen Road, Glasgow.
 FREW, JAMES, 5, Greenhill, Dunaskin, Ayr, N.B.
 FREW, JAMES, 180, Hope Street, Glasgow.
 FREW, ROBERT, 180, Hope Street, Glasgow.
 FREW, WILLIAM, Broomhouse Colliery, Broomhouse, N.B.
 FROSSARD, J. D., Orthes, Basses Pyrenees, France.
 FROST, WILLIAM, Sneyd Colliery, Burslem, Stoke-upon-Trent.
 FRYAR, JOHN WILLIAM, Job's Hill, Crook, Darlington.
 FRYAR, MARK, Denby Colliery, Derby.
 FRYAR, WILLIAM, Brisbane, Queensland, Australia.
 GALE, F. G., The Glen Deep Mining Company, Germiston, Johannesburg, Transvaal.
 GALLOWAY, ROBERT L., 43, Mair Street, Plantation, Glasgow.
 GALLOWAY, T. LINDSAY, Argyll Colliery, Campbeltown, N.B.

- GALLOWAY, W., Cardiff.
 GALLWEY, A. PAYNE, P.O. Box 138, Johannesburg, Transvaal.
 GARDINER, EDGAR T., 8, South View Terrace, Bishop Auckland.
 GARDNER, HUGH, Minas Schwager, Coronel, Chili.
 GARFORTH, W. E., West Riding Colliery, Normanton.
 GARSIDE, F., Wath Main Colliery, near Rotherham.
 GARVEN, WILLIAM, 14, Lorne Terrace, Maryhill, Glasgow.
 GATER, ENOCH, Oak Tree Cottage, Talke, Stoke-upon-Trent.
 GAVIN, JAMES, Udston Colliery, Hamilton, N.B.
 GEDDES, CHARLES D., 21, Young Street, Edinburgh.
 GEDDES, GEORGE H., 21, Young Street, Edinburgh.
 GEMMELL, JOHN, 10, St. Andrew's Square, Edinburgh.
 GERRAND, JOHN, Manager, The Langlaate Deep, Limited, P.O. Box 771,
 Johannesburg, Transvaal.
 GERRARD, JAMES, 11, Meek's Buildings, Wigan.
 GERRARD, JOHN, H.M. Inspector of Mines, Worsley, Manchester.
 GIBB, ROBERT, Glynecorwg, Cymmer, R.S.O., South Wales.
 GIBBS, HUBERT, Rookery Road, Handsworth, Birmingham.
 GIFFORD, HENRY J., Minas de Passagem, Ouro Preto, Brazil.
 GILCHRIST, JAMES, Lanemark Colliery, New Cumnock, R.S.O., Ayrshire.
 GILCHRIST, J. R., Garesfield Colliery, Lintz Green, Newcastle-upon-Tyne.
 GILL, JOHN, Lofthouse Colliery, Wakefield.
 GILL, THOMAS, Trafford Collieries, near Barnsley.
 GILL, WILLIAM, Apartado, 42, Bilbao, Spain.
 GILLESPIE, ALEXANDER, Dalmellington Iron Works, Ayr, N.B.
 GILLET, L. F., 163, Osmaston Road, Derby.
 GILLMAN, F., Gartenstrasse, 1, Freiburg, Baden, Germany.
 GILLOTT, J. W., Summer Lane, Barnsley.
 GILMOUR, ALLAN, Portland Colliery, Kilmarnock, N.B.
 GILROY, S. B., Mining Engineer, Mansfield.
 GIPPS, F. G. DE VISMÉ, Coolgardie, Western Australia.
 GJEES, JOHN, 3, Southfield Villas, Middlesbrough.
 GLEDHILL, EDWARD, c/o Andrew Hallett, Solicitor, Portland Street, Southampton.
 GLEN, JOHN, Connell Terrace, Airdrie, N.B.
 GLENNIE, W. H., Minas de Rosario, Nieves, Estado de Zacatecas, Mexico, via
 New York.
 GOKER, A., Manor House, St. John's Wood Park, London, N.W.
 GOLDIE, THOMAS, Wood Street, Blairhill, Coatbridge, N.B.
 GOLDSWORTHY ARTHUR, Linares, Provincia de Jaen, Spain.
 GOODWIN, GEORGE, Prestongrange Colliery, Prestonpans.
 GOODWIN, G. A., The Elms, Ashford, Bakewell.
 GOODWIN, WILLIAM H., Chesterton Hall, Apedale, Staffordshire.
 GOOLDEN, WALTER T., c/o Easton, Anderson and Goolden, Limited, 2, St. Nicholas'
 Buildings, Newcastle-upon-Tyne.
 GORDON, GAVIN C., Netherton, Wishaw, N.B.
 GORDON, ROBERT, Imperial Chambers, Coolgardie, Western Australia.
 GOULDIE, JOSEPH, The Gill, Aspatria, Cumberland.
 GRAHAM, EDWARD, Jun., East Howle Colliery, Ferryhill.
 GRANT, JOHN, The Grange, Larkhall, R.S.O., Lanarkshire.
 GRATTON, R. T., Knifesmith Gate, Chesterfield.
 GRAVE, L. W. DE, All Saints Works, Derby.
 GRAVES, H. G., 5, Robert Street, Adelphi, London, W.C.

- GRAY, ARCHIBALD, Middleton House, Dalry, Ayrshire.
 GRAY, ARCHIBALD, Jun., 55, Eglinton Street, Ardrossan, N.B.
 GRAY, JAMES, Riverside, Old Cumnock, N.B.
 GRAY, JOHN, Morningside Colliery, Newmains, N.B.
 GRAY, WILLIAM, Carfin Colliery (Dixon's), Motherwell, N.B.
 GRAY, WILLIAM, Common Cottage, Auchinleck, R.S.O., Ayrshire.
 GRAYSTON, F. A., Glascote House, Tamworth.
 GRAZEBROOK, A. W., Queen's Cross, Dudley, Worcestershire.
 GREATBACH, GEORGE H., Great Fenton Collieries, Stoke-upon-Trent.
 GREAVES, J. O., Westgate, Wakefield.
 GREAVES, PERCY C., Westgate, Wakefield.
 GREEN, A. T., Whiston Grove, Moorgate, Rotherham.
 GREEN, EDWIN R., Abbotsford Colliery, Abbotsford, Dunedin, New Zealand.
 GREEN, HUGO G. H., 82, Westgate, Wakefield.
 GREEN, J. T., Southside, Sneyd Park, Clifton, Bristol.
 GREENEB, HENRY, South Pontop Colliery, Annfield Plain.
 GREENER, T. Y., West Lodge, Crook, Darlington.
 GREENSMITH, JOHNSON, Newstead Colliery, Nottingham.
 GREENWELL, G. C., Jun., Poynton, near Stockport.
 GREENWOOD, W. H., Hardwicke, Carpenter Road, Edgbaston, Birmingham.
 GREGORY, AUBREY, Dhadka Colliery, Asansol, E.I.R., India.
 GREGORY, H. E., Cortonwood Collieries, West Melton, near Rotherham.
 GREGORY, JAMES, Jun., Lowood Villas, Deepcar, Sheffield.
 GREGORY, JOHN, Sneyd Colliery, Burslem, Stoke-upon-Trent.
 GREGSON, G. E., 11, Chapel Street, Preston, Lancashire.
 GRESLEY, W. S., Erie, Pennsylvania, U.S.A.
 GREY, C. G., Ballycourey, Enniscorthy, Co. Wexford.
 GREY, FREDERICK WILLIAM, Dashwood House, 9, New Broad Street, London, E.C.
 GRIFFITH, EDWARD.
 GRIFFITH, N. R., Plasnewydd, Ruabon, North Wales.
 GRIFFITHS, F., Pensnett, Dudley, Worcestershire.
 GRIFFITHS, W., Waterloo House, Aberystwyth, South Wales.
 GRIMSHAW, E. J., 23, Hardshaw Street, St. Helen's, Lancashire.
 GRUNDY, JAMES, 27, Chowringhee Road, Calcutta, India.
 GUTHRIE, JAMES K., Wylam-upon-Tyne.
- HABERSHON, M. H., Thorncliffe Iron Works and Collieries, Sheffield.
 HADDOCK, W. T., Sutherland Reef, Limited, Leydsdorp, Zoutpansberg, South African Republic.
 HADDOW, JOHN, Benquhat, Dalmellington, R.S.O., Ayrshire.
 HADFIELD, R. A., Hecla Steel Foundry, Sheffield.
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 HAGGIE, G. A., Wearmouth Ropery, Sunderland.
 HAGGIE, PETER SINCLAIR, Gateshead-upon-Tyne.
 HAGGIE, R. HOD, Jun., Box No. 5, Royal Exchange, Glasgow.
 HAGUE, ERNEST, Castle Dyke, Sheffield.
 HAIGH, WILLIAM, Colliery Owner, Dewsbury.
 HAINES, J. RICHARD, Adderley Green Collieries, Stoke-upon-Trent.
 HALDER, ALBERT H., 10, Drapers Gardens, London, E.C.
 HALL, EDGAR, Thorpe Salvin, Worksop.
 HALL, FRED., Fernleigh, Highfield, Workington.
 HALL, FRED. W., Haswell Lodge, Sunderland.

- HALL, H. R., Hazel Grove, West Park, Chesterfield.
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HALL, L. J., Furness Vale, Stockport.
HALL, M., Lofthouse Colliery, Wakefield.
HALL, M. S., 8, Victoria Street, Bishop Auckland.
HALL, TOM, Ryhope Colliery, *via* Sunderland.
HALL, W., The Firs, Pelsall, Staffordshire.
HALL, W. F., Haswell Colliery, Haswell, *via* Sunderland.
HALLAS, G. H., Wigan and Whiston Coal Company, Limited, Prescott.
HALLIDAY, JOHN, Blackhill Colliery, Maryhill.
HALLIMOND, W. T., General Manager, Cape Collieries, Limited, Molteno, Cape Colony.
HALSE, EDWARD, Sucre, Puerto Berrio, Estado de Antioquia, Republic of Colombia, South America.
HAMILTON, E., Rig Wood, Saltburn-by-the-Sea.
HAMILTON, JAMES, 208, St. Vincent Street, Glasgow.
HAMILTON, JOHN, 18, Orbiston Street, Motherwell, N.B.
HAMILTON, J. P., Bull Bridge Lime Works, Derby.
HAMILTON, LORD, Dalzell Estate Office Motherwell, N.B.
HAMILTON, ROBERT, 88, Great Clyde Street, Glasgow.
HAMILTON, WILLIAM, Niddrie Cottages, Portobello, N.B.
HANCOCK, H. L., Moonta Mines, South Australia.
HANCOCK, H. R., Moonta Mines, South Australia.
HANNAH, DAVID, Ferndale, Glamorgan.
HARDIE, JAMES, Broomknowe, Cambuslang, N.B.
HARDIE, W. D. L., Alberta Railway and Coal Company, Lethbridge, Alta, Canada
HARDWICK, FRANCIS W., Firth College, Sheffield.
HARDWICK, FREDERICK, Eckington Collieries, Sheffield.
HARK, SAMUEL, Bedlington Collieries, Bedlington, R.S.O., Northumberland.
HARGREAVES, J., Rothwell Haigh Colliery, Leeds.
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HARGREAVES, WILLIAM, Rothwell Haigh Colliery, Leeds.
HARGREAVES, W. A., Micklefield Colliery, South Milford.
HARKER, WILLIAM, Cannon Street House, London, E.C.
HARLE, PETER, Pagebank Colliery, Co. Durham.
HARLE, RICHARD, Browney Colliery, Durham.
HARPER, J. P., All Saints Chambers, Derby.
HARRIS, G. E., Margherita, Debrugarh, Upper Assam.
HARRIS, W. S., Kibblesworth, Gateshead-upon-Tyne.
HARRISON, C. A., North Eastern Railway, Newcastle-upon-Tyne.
HARRISON, G. B., H.M. Inspector of Mines, Swinton, near Manchester.
HARRISON, G. D., Waterworks, Hanley, Staffordshire.
HARRISON, JONATHAN, Kimihia, Auckland, New Zealand.
HARRISON, S., Fitzwilliam-Hemsworth Collieries, near Wakefield.
HARRISON, W. B., Brownhills Collieries, near Walsall.
HARROP, J. A., Westminster Collieries, Wrexham.
HARROP, W. M., Princess Street, Morley, Leeds.
HART, ROBERT.
HARVEY, WILLIAM PELLEW, Assay Office and Metallurgical Works, Vancouver, British Columbia.

- HARWOOD, T. H., 56, Otter Street, Derby.
- HASSAM, ARTHUR, Flimby and Broughton Moor Collieries, Maryport.
- HASSARD, W. J., 209, Sauchiehall Street, Glasgow.
- HASTIE, JAMES, Greenfield Colliery, Hamilton, N.B.
- HAWKER, EDWARD WILLIAM, Adelaide Club, Adelaide, South Australia.
- *HAWKINS, R. SPENCER, Albert Mines Syndicate, Coolgardie, Western Australia.
- HAY, J., JUN., Widdrington Colliery, Acklington.
- HAY, T. Y., Whitwick Colliery, Coalville, Leicester.
- HAY, WILLIAM, Elbey Street, Pinderfield Road, Wakefield.
- HAY, WILLIAM, Stanton Colliery, Burton-upon-Trent.
- HAYWARD, W. J., West Bromwich.
- HEAD, JEREMIAH, 47, Victoria Street, Westminster, London, S. W.
- HEATH, JAMES, 54, Cadogan Square, London, S. W.
- HEATH, JOHN, Sneyd Colliery, Burslem, Stoke-upon-Trent.
- HEATH, ROBERT, Biddulph Valley Iron Works, Stoke-upon-Trent.
- HEATH, WILLIAM, Edgefields House, Stockton Brook, Stoke-upon-Trent.
- HEDLEY, J. L., H. M. Inspector of Mines, 2, Devonshire Terrace, Newcastle-upon-Tyne.
- HEDLEY, SEPTIMUS H., Langholme, Roker, near Sunderland.
- HEDLEY, WILLIAM, Ouston House, Chester-le-Street.
- HENDERSON, H., Pelton Colliery, Chester-le-Street.
- HENDERSON, JOHN, Cornsilloch Colliery, Larkhall, R.S.O., Lanarkshire.
- HENDERSON, J. J., Executive Engineer, Shahrigh, Beloochistan, India.
- HENDERSON, J. J., U.S. Engineer's Office, Kingsbridge, New York, U.S.A.
- HENDERSON, WILLIAM, Levensat, Fauldhouse, Linlithgowshire.
- HENDY, J. C. B., Etherley, *via* Darlington.
- HENSHAW, A. MAYON, Talk-o'-th'-Hill Colliery, Talke, Stoke-upon-Trent.
- HEPBURN, WHELDON, Littleton Colliery, near Durham.
- HEPPELL, T., Leafield House, Birtley, Chester-le-Street.
- HEPPLEWHITE, W. H., H. M. Inspector of Mines, Blenheim Mount, St. Ann's Hill, Nottingham.
- HERD, THOMAS, Dunnikier Colliery, Kirkcaldy, N.B.
- HESLOP, C., Woodside, Marske Mill Lane, Saltburn-by-the-Sea.
- HESLOP, GRAINGER, Deptford Hall, Sunderland.
- HESLOP, JAMES, Sherwood Rise, Nottingham.
- HESLOP, MICHAEL, Rough Lea Colliery, Willington, Co. Durham.
- HESLOP, SEPTIMUS, New Beerbhoom Coal Company, Limited, Asansol, Bengal, India.
- HESLOP, THOMAS, Storey Lodge Colliery, Cockfield, *via* Darlington.
- HESLOP, WILLIAM TAYLOR, Central Collieries, Brakpan, Johannesburg, Transvaal.
- HEWITT, C. R., London Road, Derby.
- HEWITT, G. C., Serridge House, Coalpit Heath, near Bristol.
- HEWITT, H. R., H. M. Inspector of Mines, 23, Hartington Street, Derby.
- HEWITT, T. P., Castle Gresley, Burton-upon-Trent.
- HEWLETT, A., Haseley Manor, Warwick.
- HEWLETT, ERNE, Ammanford Colliery Company, Limited, Ammanford, R.S.O., Carmarthenshire.
- HICKS, W. M., Firth College, Sheffield.
- HIGBY, ROBERT GEORGE, Borrea Coal Company, Limited, Salanpore Collieries, Seetarampore, Bengal, India.
- HIGGINS, SAMUEL, Weston Coyney Road, near Longton, Staffordshire.
- HIGSON, JACOB, Crown Buildings, 18, Booth Street, Manchester.

- HIGSON, JOHN, Crown Buildings, 18, Booth Street, Manchester.
 HILL, JAMES, Helenbank Cottage, Dalmellington, R.S.O., Ayrshire.
 HILL, LESLIE, Calgary, Alta, Canada.
 HILL, THOMAS, Codnor Park, Alfreton.
 HILL, WILLIAM, The Pooley Hall Colliery Company, Polesworth, near Tamworth.
 HILTON, JAMES, Woodcock Hall, Newburgh, near Southport.
 HILTON, T. W., Wigan Coal and Iron Company, Limited, Wigan.
 HINCHLIFFE, HERBERT, Bullhouse Colliery, Penistone, near Sheffield.
 HINCHLIFFE, J., Bullhouse Colliery, Penistone, near Sheffield.
 HOBBS, WILLIAM L., Whitfield Collieries, Norton-in-the-Moors, Stoke-upon-Trent.
 HOBSON, J. B., Cariboo Hydraulic Mining Company, Limited, Vancouver, British Columbia.
 HODGE, FRANCIS, Coromandel, near Auckland, New Zealand.
 HODGES, ISAAC, Whitwood Collieries, Normanton.
 HODGSON, JACOB, Cornsley Colliery, Co. Durham.
 HODGSON, J. Edmondsley Colliery, Chester-le-Street.
 HODGSON, L. H., The Consolidated Anthracite Collieries Company, Limited, Garnant, R.S.O., South Wales.
 HODSON, JAMES, Hill House, Croppers Hill, St. Helen's, Lancashire.
 HOFFMAN, CHARLES, Per Private Bag, P.O. Box 1022, Johannesburg, Transvaal.
 HOGG, C. E., 1, St. Helen's Place, London. E.C.
 HOGG, JAMES, Kirkhill Colliery, Cambuslang, Glasgow.
 HOGG, JOHN, Ardoch Grove, Cambuslang, Glasgow.
 HOGG, JOHN, Victoria Engine Works, Airdrie, N.B.
 HOLBROOK, JOHN, Langley Colliery, Maripool, Derby.
 HOLDING, WILLIAM, Cossall Colliery, Nottingham.
 HOLFORD, W. D., Whittington, Chesterfield.
 HOLIDAY, ROSLYN, Ackton Hall Colliery, Featherstone, near Pontefract.
 HOLLIDAY, MARTIN F., Langley Grove, Durham.
 HOLLIDAY, T., Kippax Colliery, Allerton Bywater, Castleford.
 HOLLINGS, JOHN H., Wath Main Colliery, Rotherham.
 HOLLINGWORTH, G. H., 12, King Street, Manchester.
 HOLLINS, G., High Street, Wolstanton, Stoke-upon-Trent.
 HOLLIS, HENRY WILLIAM, Whitworth House, Spennymoor.
 HOLLOWAY, GEORGE, Hamstead Colliery, Great Barr, Birmingham.
 HOLMAN, J. M., Hill Crest, Camborne, Cornwall.
 *HOLMES, C., 109, Victoria Road, Darlington.
 HOLT, JOHN, Jun., 109, Manchester Road, Swinton, Lancashire.
 HOMAN, WILLIAM McLEAN, Assistant Engineer, Kroonstad, Orange Free State, South Africa.
 HOOD, A., 6, Bute Crescent, Cardiff.
 HOOD, JAMES A., Rosewell, Midlothian.
 HOOPER, EDWARD, c/o J. H. Hooper, College Precincts, Worcester.
 HOOPER, G. C., General Manager, Afrikander Gold Mining Company, Limited, Klerksdorp, South African Republic.
 HOPKINS, EDWARD, 13, Harrington Gardens, London, S.W.
 HOPKINSON, HENRY, Station Street, Nottingham.
 HOPKINSON, JOHN, Inglewood, St. Margaret's Road, Bowden, Cheshire.
 HORNE, THOMAS L., Twechar Works, Kilsyth, N.B.
 HORSFIELD, A., 1, Reginald Terrace, Leeds.
 HOSKING, JAMES, Roskear, Camborne, Cornwall.

- HOSKOLD, CARLOS A. LYNES, First Engineer, Inspector of the National Department of Mines and Geology, Calle Charcas, 1,222, Buenos Aires, Argentine Republic.
- HOSKOLD, H. D., Inspector General of Mines of the Argentine Republic, and Director of the National Department of Mines and Geology, Buenos Aires, Argentine Republic.
- HOUFTON, CHARLES, Heathfield Villas, Garforth, Leeds.
- HOUFTON, J. P., Bolsover Colliery, Chesterfield.
- HOUSE, JOHN, Rosebridge and Douglas Bank Collieries Company, Limited, Wigan.
- HOUSTON, JAMES, Carmuir Colliery, Larbert, Stirlingshire.
- HOWARD, W. F., 15, Cavendish Street, Chesterfield.
- HOWAT, ROBERT M., 32, Victoria Street, Westminster, London, S.W.
- HOWAT, WILLIAM, Rankinston Works, Ayr, N.B.
- HOWAT, WILLIAM, Sundrum, Coylton, Ayr, N.B.
- HOWE, WILLIAM, Clay Cross, Chesterfield.
- HOWELL, J. C., New Dock, Llanelly, South Wales.
- HOWES, FRANK T., Singareni Collieries, Hyderabad Deccan Company, Secundarabad, India.
- HOWIE, JOHN, Machan Colliery, Larkhall, R.S.O., Lanarkshire.
- HOWIESON, ROBERT, Glebe Park, West Calder, N.B.
- HOWL, E., The Quarries, Dudley, Worcestershire.
- HOWLEY, JAMES PATRICK, Geological Survey of Newfoundland, Museum and Office, P.O. Building, St. John's, Newfoundland.
- HUBBERSTY, H. A., Burbage, Buxton.
- HUGH, JAMES, Thornhill, Blantyre, Glasgow.
- HUGHES, H. W., 188, Wolverhampton Street, Dudley, Worcestershire.
- HUGHES, T. VAUGHAN, Princes Chambers, 6, Corporation Street, Birmingham.
- HULL, Prof. E., 20, Arundel Gardens, London, W.
- HUMBLE, JOSEPH, Markham Collieries, Duckmanton, Chesterfield.
- HUMBLE, WILLIAM, Lawson Street, Hamilton, Newcastle, New South Wales.
- HUNT, WALFORD, Cinder Hill, Nottingham.
- HUNTER, ANDREW, Alloa Colliery, Alloa, N.B.
- HUNTER, DAVID, 101, St. Vincent Street, Glasgow.
- HURLL, MARK, 144, West Regent Street, Glasgow.
- HURST, GEORGE, 9, Framlington Place, Newcastle-upon-Tyne.
- HURST, G. A., Dosthill, near Tamworth.
- HUTCHINSON, R. L., 83, Howard Street, North Shields.
- HYSLOP, G. P., The Madeley Coal and Iron Company, Limited, Madeley, near Newcastle, Staffordshire.
- HYSLOP, JONATHAN, Greenbank, Coatbridge, N.B.
- INGLIS, PETER, Plean Colliery, Bannockburn, N.B.
- INGRAM, ARTHUR EDGAR, Buluwayo, Matabeleland, South Africa.
- IRVINE, JOHN, Halbeath Colliery, Dunfermline, N.B.
- ISHERWOOD, JONATHAN, Hodroyd Colliery, Barnsley.
- JACKSON, C. F., Talbot Place, Sheffield.
- JACKSON, DAVID, Glengyron, Old Cunnock, N.B.
- JACKSON, DOUGLAS, Coltness Iron Works, Newmains, N.B.
- JACKSON, H. H., Colley Gate, Cradley, Staffordshire.
- JACKSON, JOHN, Stubben Edge, Chesterfield.

- JACKSON, W. B. M., Clay Cross Hall, Chesterfield.
 JACKSON, W. G., High Prestwick, Chiddingfold, Surrey.
 JAFFREY, WILLIAM, Westminster Chambers, 3, Victoria Street, London, S.W.
 JAMES, WILLIAM HENRY TREWARTHA, 38, Aberdare Gardens, West Hampstead, London, N.W.
 JAMIESON, ALEXANDER, Balgonie Colliery, Markinch, N.B.
 JAMIESON, J. AULDJO, 66, Queen Street, Edinburgh.
 JAMIESON, T. J., Motherwell Colliery, Motherwell, N.B.
 JARRATT, J., Houghton Main Colliery, Barnsley.
 JEFFCOCK, C. E., Birley Collieries, Sheffield.
 JEFFCOCK, T. W., 18, Bank Street, Sheffield.
 JENKINS, W., Ocean Collieries, Treorchy, R.S.O., Glamorganshire.
 JEPSON, H., 39, North Bailey, Durham.
 JOBLING, JOHN WILLIAM, Clifton Cottage, Burnley, Lancashire.
 JOBLING, T. E., Bebside, Northumberland.
 JOHNS, J. HARRY, Ferreira Gold Mining Company, Limited, P.O. Box 1021, Johannesburg, Transvaal.
 JOHNSON, ALGERNON EDWARD, County Court Buildings, Wrexham.
 JOHNSON, GUY ROCHE, P.O. Box 75, Embreville, Washington County, Tennessee, U.S.A.
 JOHNSON, HENRY, Trindle Road, Dudley, Worcestershire.
 JOHNSON, J., The Terrace, Stairfoot, near Barnsley; and Charbonnages de Rodez, Limited, Gages, Aveyron, France.
 JOHNSON, W., Abram Colliery, Wigan.
 JOHNSON, WILLIAM, 3, Elm Grove, Warkworth.
 JOHNSTON, ANDREW, Minas de Rio Tinto, Provincia de Huelva, Spain.
 JOHNSTON, D. S., P.O. Box 116, Johannesburg, Transvaal.
 JOHNSTON, J. HOWARD, c/o Backus and Johnston, Lima, Peru, South America.
 JOHNSTONE, HUGH, 77, Montgomery Street, Kelvinside North, Glasgow.
 JOHNSTONE, JAMES, Belhaven Road, Wishaw, N.B.
 JOHNSTONE, RONALD H., 238, West George Street, Glasgow.
 JOICEY, J. G., Forth Banks West Factory, Newcastle-upon-Tyne.
 JOICEY, W. J., Sunningdale Park, Berks.
 JONAS, GEORGE B., 15, Gordon Street, Glasgow.
 JONES, ENOS, Whitwell Colliery, Whitwell, Chesterfield.
 JONES, F. J., Rother Vale Collieries, Treeton, Rotherham.
 JONES, ISAAC, Wynnstay Collieries, Ruabon.
 JONES, J. A., Gijon, Asturias, Spain.
 JONES, JACOB CARLOS, Bellambi, New South Wales.
 JONES, LLOYD, Plasisa, Rhosymedre, Ruabon, North Wales.
 JONES, THOMAS, 1, Princes Street, Great George Street, London, S.W.

 KANDA, REIJI, Shikaibetsu Silver and Lead Mines, Yoichi, Hokkaido, Japan.
 KAUFMAN, CHARLES, St. George's Terrace, Perth, Western Australia.
 KAY, ROBERT, South Tanfield, Stanley, R.S.O., Co. Durham.
 KAY, THOMAS W., Jherria P.O., District Manbhoom, Bengal, India.
 KAYLL, A. C., Gosforth, Newcastle-upon-Tyne.
 KAYSER, H. W. FERDINAND, The Mount Bischoff Tin Mining Company, Waratah, Tasmania.
 KEELER, JULIAN A., The Colorado Fuel and Iron Company, Boston Building, Denver, Colorado, U.S.A.
 KEIRS, JOHN, Drongan Castle Colliery, Drongan, Ayr, N.B.

- KELL, G. J., Beech Grove, Locke Park, Barnsley.
 KELLET, M. H., St. Helen's Colliery, Bishop Auckland.
 KELLETT, WILLIAM, Portland Bank, Southport.
 KENNEDY, HENRY.
 KENNEDY, WILLIAM, 509, West Sixth Street, Austin, Texas, U.S.A.
 KENRICK, JOHN P., 8, St. James' Square, Manchester.
 KERR, ARCHIBALD, Mayville, Cleland, Lanarkshire, N.B.
 KESTIVEN, FRANK, Monckton Main Colliery, Barnsley.
 KIDD, THOMAS, Jun., c/o Thomas Kidd, 104, Balham Park Road, Balham,
 London, S. W.
 KILPATRICK, JOHN B., Brownieside House, Airdrie, N.B.
 KILPATRICK, WILLIAM M., Struther Colliery, Larkhall, N.B.
 KING, HENRY, Daldowie Colliery, Broomhouse, Glasgow.
 KIRKBY, J. W., Kirkland, Leven, Fife.
 KIRKBY, RICHARD, Wellsgreen Colliery, Windygates, R.S.O., Fife.
 KIRKUP, AUSTIN, Newbottle Colliery, Bunker Hill, Fence Houses.
 KIRKUP, J. P., Burnhope, near Lanchester.
 KIRKUP, PHILIP, Cornsray Colliery Office, Esh, near Durham.
 KIRKWOOD, WILLIAM A., Clydeview, Larkhall, R.S.O., Lanarkshire.
 KIRTON, HUGH, Kimblesworth Colliery, Chester-le-Street.
 KLAUKE, JOSEF, Esh Village, Co. Durham.
 KNOWLES, JOHN, Brynn Mount, Westwood, Ince, Wigan.
 KNOWLES, ROBERT, Ednaston Lodge, Derby.
 KNOX, JAMES, Rosebank Villa, Tranent, N.B.
 KONDO, R., 7, Setomoncho, Nihonbashi, Tokio, Japan.
 KWANG, KWONG YUNG, c/o Chinese Engineering and Mining Company, Lin Si
 Colliery, Tientsin, North China.

 LAIRD, ANDREW, 121, West Regent Street, Glasgow.
 LAMB, GEORGE, Butterley Park, Butterley, Derby.
 LAMB, R. O., West Denton, Newcastle-upon-Tyne.
 LANCASTER, JOHN, Ashlawn, Rugby.
 LANCASTER, JOHN, Heathfield, Lesmahagow, R.S.O., Lanarkshire.
 LANDALE, A., Comely Park Place, Dunfermline.
 LANDERO, CARLOS F. DE, c/o Real del Monte Company, P.O. Box 1, Pachuca,
 Mexico.
 LANDLESS, JOHN, Bank Hall Colliery, Burnley.
 LAPORTE, H., 57, Rue de la Concorde, Brussels.
 LARMOUTH, WILLIAM.
 LATHAM, CHARLES, University College, Nottingham.
 LAURIE, JOHN, Green Street, Bothwell, N.B.
 LAVERICK, JAMES, South Kirkby Colliery, near Wakefield.
 LAVERICK, J. H. W., Pye Hill House, near Alfreton.
 LAVERICK, JOHN WALES, Tow Law Colliery Office, Tow Law, R.S.O., Co.
 Durham.
 LAVERICK, ROBERT, West Rainton, Fence Houses.
 LAWLEY, J., Cradley Road, Cradley Heath, Staffordshire.
 LAWN, JAMES GUNSON, South African School of Mines, Kimberley, South
 Africa.
 LAWRENCE, H., 24, Grainger Street West, Newcastle-upon-Tyne.
 LAWRENCE, H. L., 1, Princes Terrace, Brighton.
 LAWS, W. G., Town Hall, Newcastle-upon-Tyne.

- LAWTON, GEORGE E., Harecastle Colliery, Harecastle, Staffordshire.
 LEA, H., 38, Bennett's Hill, Birmingham.
 LEACH, C. C., Seghill Colliery, Northumberland.
 LEBOUR, G. A., Durham College of Science, Newcastle-upon-Tyne.
 LECK, WILLIAM, H.M. Inspector of Mines, Cleator Moor, Cumberland.
 LEE, JOHN F., Glapwell Colliery, Chesterfield.
 LEE, J. W. R., 70, St. Helen's Gardens, North Kensington, London, W.
 LEES, T. G., Clifton Colliery, Nottingham.
 LEWIN, HENRY W., 154, West Regent Street, Glasgow.
 LEWIS, GEORGE, Albert Street, Derby.
 LEWIS, G. ALFRED, Penshurst, Charnwood Street, Derby.
 LEWIS, HENRY, Annesley Colliery, Nottingham.
 LEWIS, H. R., Finsbury Circus Buildings, London, E.C.
 LEWIS, SIR WILLIAM THOMAS, Bart., Mardy, Aberdare.
 LIDDELL, JOHN.
 LIDDELL, J. M., 3, Victoria Villas, Newcastle-upon-Tyne.
 LINDAY, GEORGE, Blakett Colliery, Haltwhistle.
 LINDAY, JAMES, Nostell Colliery, near Wakefield.
 LINDLEY, EDWARD, Eastwood, Nottingham.
 LINDOP, A. B., Blackball, *via* Greymouth, New Zealand.
 LINDOP, J., Lime Tree House, Bloxwich, Walsall.
 *LINSLEY, R., Cramlington Colliery, Northumberland.
 LISHMAN, R. R., South Hill House, Timsbury, near Bath.
 LISHMAN, T., Hetton Colliery, Hetton-le-Hole, R.S.O.
 LISHMAN, WILLIAM, Holly House, Witton-le-Wear.
 LISHMAN, W. E., South Hetton Colliery, *via* Sunderland.
 LISLE, J., The Ottos Kopje Diamond Mines, Limited, Ottos Kopje Chambers,
 P.O. Box 381, Kimberley, South Africa.
 LITTLE, GILBERT, Transport Appliance Works, Smethwick, Birmingham.
 LIVEING, E. H., 52, Queen Anne Street, Cavendish Square, London, W.
 LIVESKY, C., Bradford Colliery, near Manchester.
 LIVESKY, T., Bradford Colliery, near Manchester.
 LIVINGSTONE, ARCHIBALD, Gladstone Terrace, Ballymena, Ireland.
 LLEWELLYN, DAVID MORGAN, Glanwern Offices, Pontypool.
 LLEWELYN, F. W., Alsager, Cheshire.
 LLOYD, G. HAMILTON, 7, St. Mildred's Court, Poultry, London, E.C.
 LOCHHEAD, JOHN A., Melita Cottage, Denny, N.B.
 LOCKETT, JAMES, Mill Hayes House, Brindley Ford, Stoke-upon-Trent.
 LOGAN, WILLIAM, Langley Park Colliery, Durham.
 LONGBOTHAM, J., Barrow Collieries, Barnsley, Yorkshire.
 LONGBOTHAM, R. H., Ings Foundry, Wakefield.
 LONGDEN, J. A., Stanton-by-Dale, Nottingham.
 LONGRIDGE, CAPTAIN CECIL CLEMENT, Grove Cottage, Gravesend.
 LONGRIDGE, J., Coxlodge Colliery, Newcastle-upon-Tyne.
 LORD, EDWARD IVEAGH, Greymouth, Westland, New Zealand.
 LOUIS, D. A., 77, Shirland Gardens, London, W.
 LOUIS, H., 11, Summerhill Terrace, Newcastle-upon-Tyne.
 LOVE, ISAAC, The Shotts Iron Company, Castlehill Collieries, by Carlisle, N.B.
 LOVE, JOHN, Lynedoch Cottage, Loanhead, N.B.
 LOVELY, W. H. C., Coolgardie, Western Australia.
 LOWDEN, T., Hamsteels, near Durham.
 LOWRANCE, T. B., Pitt Street, Barnsley.

- *LUCAS, ROBERT, Roseberry Villa, Alsager, Cheshire.
 LUCAS, SAMUEL, Dronfield Foundry, Dronfield, Sheffield.
 LUPTON, ARNOLD, 6, De Grey Road, Leeds.
 LYMN, A., Fir Tree Villa, Lower Ince, Wigan.
- MACALPINE, G. W., Altham and Great Harwood Collieries, Accrington.
 MACARTHUR, J. S., 108A, Hope Street, Glasgow.
 MCBRIDE, JOHN, Merryton Colliery, Hamilton, N.B.
 MCCABE, H. O., Russell Vale, Wollongong, New South Wales.
 MCCAFFERY, R. S., Casapalca, Peru.
 MCCALLUM, JOHN A., Jun., 5, Broomhill Terrace, N. Partick, Glasgow.
 MCCARTHY, E. T., c/o Colonel Pigott, Archer Lodge, Charles Road, St. Leonards-on-Sea.
 MCCONNELL, JAMES I., Burnfoot, Sanquhar, R.S.O., Dumfriesshire.
 MCCREATH, GEORGE W., 208, St. Vincent Street, Glasgow.
 MCCREATH, JAMES, 208, St. Vincent Street, Glasgow.
 MCCULLOCH, DAVID, 27, Oswald Street, Glasgow.
 MCCULLOCH, WILLIAM, Linkieburn House, Muirkirk, R.S.O., Ayrshire.
 McDONALD, JOHN, Jun., Parkhead Cottage, Polmont Station, Stirlingshire.
 MACDONALD, SYMINGTON, The Great Kanawha Colliery Company, Limited, Mount Carbon, West Virginia, U.S.A.
 McFARLANE, NIGEL, Kirkton, High Blantyre, Glasgow.
 McGEACHIE, DUNCAN, Waratah Colliery, Charlestown, Newcastle, New South Wales.
- McGOWAN, JOHN, Harecastle and Woodshutts Collieries, Stoke-upon-Trent.
 McGOWAN, JOHN, Jun., Harecastle and Woodshutts Collieries, Stoke-upon-Trent.
 MACHEN, WILLIAM, Church Street, Mortonley, Sheffield.
 MACKAY, ANDREW, Grangemouth Coal Company, Grangemouth, N.B.
 MACKAY, JAMES, Avonview Cottage, Avonbridge, Stirlingshire.
 MACKAY, MUNGO, Newbattle Collieries, Dalkeith, N.B.
 MACKINTOSH, JAMES, c/o T. and R. B. Ranken, 68, Queen Street, Edinburgh.
 McLAREN, B., Jun., Portland House, Kirkby-in-Ashfield, Nottingham.
 McLAREN, ROBERT, Bonny, Uddingston, Glasgow.
 McLAREN, WILLIAM, Duntroon, Tollcross, Glasgow.
 McLAUCHLAN, J. D., 19, St. Ninian's Terrace, Morningside Drive, Edinburgh.
 McMILLAN, JAMES, Jun., Langloan, Coatbridge, N.B.
 McMILLAN, JOHN, Elphinstone, Tranent, N.B.
 McMURTRIE, G. E. J., Foxes Bridge Colliery, Cinderford, Gloucestershire.
 McMURTRIE, J., Radstock Colliery, Bath.
 McNAB, JOHN.
 McNAUGHTON, JAMES, 52, St. Enoch Square, Glasgow.
 McPHAIL, JAMES, North Motherwell Colliery, Motherwell, N.B.
 McPHEE, RICHARD, Bothwell Castle Colliery, Bothwell, Glasgow.
 McVIE, JAMES, Cadzow Colliery, Hamilton, N.B.
 MADDISON, THOMAS R., Dirtcar House, near Wakefield.
 MADDISON, W. H. F., The Lindens, Darlington.
 MADDOCK, JAMES, Colliery Manager, Maddock Brook Villa, Alsager, Cheshire.
 MAKEPEACE, H. R., H.M. Inspector of Mines, Newcastle, Staffordshire.
 MALCOLM, JAMES, Arniston Colliery, Gorebridge, N.B.
 MALING, C. T., Ellison Place, Newcastle-upon-Tyne.
 MALTBY, H. E., Lidgett Colliery, Tankersley, Barnsley.
 MAMMATT, J. E., 1, Albion Place, Leeds.

- MANN, ENOCH**, Blakeley House, Dilhorne, Stoke-upon-Trent.
MARKHAM, C. P., Broad Oaks Iron Works, Chesterfield.
MARKHAM, G. E., Coundon, Bishop Auckland.
MARKE, HERBERT T., New Broad Street House, London, E.C.
MARLEY, J. W., Thornfield, Darlington.
MARRIOTT, HUGH FREDERICK, c/o H. Eckstein and Company, P.O. Box 149,
 Johannesburg, Transvaal.
MARSH, P. N., Cliffe, Tamworth.
MARSH, T. G., 206, Wolverhampton Street, Dudley, Worcestershire.
MARSHALL, JOHN, Sea More House, Stevenston, Ayrshire.
MARSHALL, J. L., Monk Bretton Colliery, Barnsley.
MARSHALL, W., Liversedge Colliery, Liversedge, *via* Normanton.
MARSHALL, WILLIAM, 15, South Street, Lochgelly, Fifeshire.
MARTEN, E. B., Pedmore, near Stourbridge.
MARTIN, C. W., Newbottle Colliery Offices, Fence Houses.
MARTIN, GILSON, Edensor, Bakewell.
MARTIN, RALPH, Cardigan Stone Company, Limited, Llandyssil, South Wales.
MARTIN, ROBERT, Niddrie Collieries, Portobello, N.B.
MARTIN, R. F., Mountsorrel, Loughborough.
MARTIN, TOM PATTINSON, 4, Curzon Street, Maryport.
MATHIESON, ALEXANDER, Hetton Colliery, Carrington, near Newcastle, New
 South Wales.
MATTHEWS, D. H. F., H.M. Inspector of Mines, Hoole, Chester.
MATTHEWS, J., c/o R. and W. Hawthorn, Newcastle-upon-Tyne.
MATTHEWS, R. F., Harehope Hall, Alnwick.
MAURICE, WILLIAM, Swanwick Collieries, Alfreton.
MAVOR, SAMUEL, 37, Burnbank Gardens, Glasgow.
MAWSON, R. BRYHAM, Brick House, Westleigh, near Manchester.
MAY, GEORGE, The Harton Collieries, South Shields.
MAY, T. H., Dronfield, Sheffield.
MAYDEW, BENJAMIN, Bentinck House, Kirkby-in-Ashfield, Nottingham.
MAYES, G. R., Wynnstay Collieries, Limited, Ruabon, North Wales.
MEACHEM, F. G., Hillside Cottage, Hamstead Hill, Handsworth, Birmingham.
MEACHEM, ISAAC, JUN., Perry Park House, Old Hill, Staffordshire.
MEIKLE, HUGH, c/o Mrs. Wilson, 270, Great Western Road, Glasgow.
MEIN, JAMES, South Normanton Colliery, Alfreton.
MELDRUM, J. J., Atlantic Works, City Road, Manchester.
MELLING, WILLIAM, South Leicestershire Colliery, Coalville, Leicestershire.
MELLON, HENRY, Brook Lea, Askam-in-Furness.
MELLORS, JAMES, H.M. Inspector of Mines, Outwood, Wakefield.
MELLY, E. F., Griff Colliery, Nuneaton.
MENZIES, JOHN, Auchinraith Colliery, Blantyre, Glasgow.
MERIVALE, J. H., Togston Hall, Acklington, Northumberland.
MERIVALE, W., Managing Director, Barbados Railway, Barbados, W.I.
MERRITT, W. HAMILTON, 90, Bloor Street East, Toronto, Ontario, Canada.
METCALF, A. T., Joes Reef United (Sheba), Limited, Eureka City, De Kaap,
 South African Republic.
MEYER, G. A., Shamrock Collieries, Westphalia.
MEYSEY-THOMPSON, A. H., Sun Foundry, Leeds.
MIDDLETON, FRANÇOIS EDWARD, Lofthouse, Wakefield.
MIDDLETON, GEORGE, 194, Saracen Street, Possil Park, Glasgow.
MIDDLETON, ROBERT, Sheep Scar Foundry, Leeds.

- MILLAR, ROBERT, Balgray Cottage, Maryhill, Glasgow.
 MILLER, GEORGE APPLEBY BARTRAM, Leighton Road, Southville, Bristol.
 MILLER, JAMES, Minas de Sao Bento, Santo Barbara de Matto Dentro, Minas Geraes, Brazil.
 MILLER, JOHN D., Rosehall Colliery, Coatbridge, N.B.
 MILLER, J. P. K., H. C. Frick Coke Company, Scottdale, Pennsylvania.
 MILLER, WILLIAM, Equitable Coal Company, Barrakur, E.I. Railway, Bengal, India.
 MILLER, W. M., 12, St. Andrew Square, Edinburgh.
 MILLIGAN, PETER, Morrisonshaven, Prestonpans.
 MILLS, M. H., Sherwood Hall, Mansfield.
 MILLWARD, GEORGE A., Shelton Iron, Steel and Coal Company, Limited, Stoke-upon-Trent.
 MILNE, JOHN, Shide Hill House, Shide, Newport, Isle of Wight.
 MITCHELL, GEORGE A., 5, West Regent Street, Glasgow.
 MITCHELL, JOHN, Delta House, Inveresk, Musselburgh, N.B.
 MITCHELL, J. E., Mining Offices, Barnsley.
 *MITCHELL, THOMAS, Atacama Mineral Company, Limited, Taltal, Chili.
 MITCHELL, T. W. H., Mining Offices, Barnsley.
 MITCHESON, G. A., Market Place, Longton, Staffordshire.
 MITCHINSON, R., Pontop Colliery, Annfield Plain, R.S.O., Co. Durham.
 MITTON, A. DURY, Oakwood, Walkden, near Bolton, Lancashire.
 MOLLER, WARDEN APPLEBY, Hangchow, China.
 MOLSON, C. A., Elkhorn Mining Company, Limited, Elkhorn, Jefferson County, Montana, U.S.A.
 MONKHOUSE, JOSEPH, Gilcrux, Carlisle.
 MOODIE, THOMAS, Bonkle, Newmains, N.B.
 MOORE, R. T., 156, St. Vincent Street, Glasgow.
 MOORE, R. W., Somerset House, Whitehaven.
 MOORE, THOMAS, Shipley Colliery, Derby.
 MOORE, WILLIAM, Loftus Mines, Loftus-in-Cleveland, R.S.O.
 MOREING, C. A., Broad Street House, Old Broad Street, London, E.C.
 MORGAN, C. R., Hurst Lodge, Alfreton.
 MORGAN, DANIEL, Stratton-on-the-Fosse.
 MORGAN, EDWIN, 23, Dairyhouse Road, Derby.
 MORISON, JOHN, Cramlington House, Northumberland.
 MORLAND-JOHNSON, EDWARD THOMAS, 1, Bryn Bowydd, Blaenau Festiniog, North Wales.
 MORRIS, W., Waldrige Colliery, Chester-le-Street.
 MORSE, WILLARD S., Hacienda de Guadalupe, Huantla, Estado Morelos, Mexico.
 MORTON, H. J., 2, Westbourne Villas, Scarborough.
 MORTON, JAMES, Manor Park, Blairhill, Coatbridge, N.B.
 MORTON, JAMES, Glen Villa, Charlestown, Fife.
 MORTON, JOHN.
 MORTON, JOHN, 8, Garden Street, Galston, R.S.O., Ayrshire.
 MORTON, R. M., Ansonhill House, Crossgates, R.S.O., Fifeshire.
 MORTON, W. S., Baton Colliery, Shotts, N.B.
 MOSES, WILLIAM, The Transvaal Coal Trust Company, Limited, Brakpan Colliery, Johannesburg, Transvaal. Per Brakpan Private Bag.
 MOTTRAM, A. H., Bourtreehill Colliery, Dregghorn, R.S.O., Ayrshire.
 MOTTRAM, T. H., 6, Kelvinside Gardens, Glasgow.
 MOUNTAIN, WILLIAM C., Forth Banks, Newcastle-upon-Tyne.

- MOWAT, DAVID M., Summerlee Iron Works, Coatbridge, N.B.
 MUDDIMAN, J. D., 14, Park Avenue, Albert Park, West Didsbury, Lancashire.
 MUIR, J. HARVEY, 140, Bath Street, Glasgow.
 MUIR, ROBERT, Bog Colliery, Larkhall, N.B.
 MUIR, ROBERT A., Lindsay Place, Blairadam, Kinross-shire.
 MUIR, W. W., Douglas Colliery, Lanark, N.B.
 MUNDLE, ARTHUR, Bank Chambers, 24, Grainger Street West, Newcastle-upon-Tyne.
 MUNGALL, HENRY, Cowdenbeath Collieries, Cowdenbeath, R.S.O., N.B.
 MUNGALL, WALTER H., Transy, Dunfermline, N.B.
 MUNRO, DONALD, Fairfield, Manchester.
 MUNRO, JAMES, Quarter Collieries, Hamilton N.B.
 MUNRO, NEIL, Gavell Cottage, Kilsyth, Glasgow.
 MUNRO, R. D., 13, Dundas Street, Glasgow.
 MUNROE, H. S., Columbia College, 41, East Fortyninth Street, New York, U.S.A.
 MURRAY, JAMES, New Orbiston, Bellshill, N.B.
 MURRAY, JOHN, Raneegunge Coal Association, Limited, Giridih, India.
 MURRAY, ROBERT, Benvue, Bo'ness, R.S.O., Linlithgowshire.
 MURTON, CHARLES J., Barrow Collieries, Barnsley, Yorkshire.
 MUSCHAMP, PERCIVAL, Warren Grove, Sheffield Road, Barnsley.
 MUSGRAVE, HENRY, Havercroft Main Colliery, Roystone, near Barnsley.
 MYATT, JACOB, Newchapel, Tunstall, Staffordshire.
- NAPIER, JAMES, Leven Bank, Cambuslang, Glasgow.
 NASH, H. B., Clarke's Old Silkstone Colliery, Barnsley.
 NASMYTH, A. H., Donibristle Colliery, Crossgates, R.S.O., Fifeshire.
 NASMYTH, G. B., Dundonald, Cardenden, R.S.O., Fifeshire.
 NASSE, RUDOLPH, Geheimer Oberbergrath, Dörnbergstrasse, 6, Berlin, W., Germany.
 NEAVE, HENRY EDWARD.
 NEILSON, GEORGE, Crossbasket, High Blantyre, Glasgow.
 NESS, HENRY, Townhill, Dunfermline, N.B.
 NEVILLE, P., Walsall Wood, Walsall.
 NEVIN, JOHN, Littlemoor House, Mirfield.
 NEWBIGIN, H. T., 15, Chester Crescent, Newcastle-upon-Tyne.
 NEWBOULD, T., Low Stubbin Colliery, Rawmarsh, Rotherham.
 NEWTON, JAMES, Whitehaven Colliery, Whitehaven.
 NEWTON, JOHN, Longport, Stoke-upon-Trent.
 NICHOLSON, J. COOK, Collingwood Street, Newcastle-upon-Tyne.
 NICHOLSON, J. H., Cowpen Colliery Office, Blyth, Northumberland.
 NICHOLSON, MARSHALL, Middleton Colliery, Leeds.
 NIMMO, JAMES, 12, St. Giles Street, Edinburgh.
 NISBET, ANDREW, Lochgelly Colliery, Lochgelly, R.S.O., Fifeshire.
 NISBET, HENRY, Comely Bank, Leven, Fifeshire.
 NISBET, JAMES, 208, St. Vincent Street, Glasgow.
 NIVISON, JOHN, Dykehead Colliery, Larkhall, R.S.O., Lanarkshire.
 NOBLE, THOMAS GEORGE, Sacriston Colliery, Durham.
 NORTH, F. W., 18, St. Swithin's Lane, London, E.C.
 NORTHOOTT, CEIL E., c/o G. Graves Gifford, Chancery Chambers, Coolgardie, Western Australia.

NOWELL, ARTHUR BERRY, Margherita, Upper Assam, India.

NOWELL, WILLIAM, Haunchwood Colliery, Nuneaton.

OAKES, C. H., Newlands, Alfreton.

OATES, R. J. W., Manager, Government Central Provinces Collieries, Umaria,
via Katni, C.P., India.

O'DONAHUE, T. A., 35, Princess Street, Wigan.

OFFER, STEPHEN, The Elms, Cheadle, Staffordshire.

*OGILVIE, A. GRAEME, 8, Grove End Road, St. John's Wood, London.

OKE, F. R., 5, Coppenhall Terrace, Crewe.

OLDHAM, GEORGE, 25, Western Hill, Durham.

OLIVER, C. J., Spring Vale, Spital, Chesterfield.

OLIVER, SEPTIMUS, Tyne House, Tynemouth.

ORMISTON, A. R., 203, St. Vincent Street, Glasgow.

ORMISTON, JAMES, 203, St. Vincent Street, Glasgow.

ORR, THOMAS, Bredisholm Colliery, Uddingston, Glasgow.

O'SHEA, L. T., Firth College, Sheffield.

OVEREND, JAMES, Mining Offices, Regent Street, Barnsley.

OWEN, JAMES L., 120, Colmore Row, Birmingham.

PACEY, J. WILLIAM, 3, Main Street, Stapenhill, Burton-upon-Trent.

PALMER, A. S., 3, Victoria Square, Newcastle-upon-Tyne.

PALMER, C. B., Wardley Hall, near Newcastle-upon-Tyne.

PALMER, SIR CHARLES MARK, Bart., M.P., Quay, Newcastle-upon-Tyne. Trans-
actions to be sent to The Mechanics' Institute, Felling-upon-Tyne.

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PAMELY, C., Wye Cliff House, Welsh Street, Chepstow.

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PARSONS, C. E., United Australian Exploration, Limited, Equitable Buildings,
Sydney, New South Wales.

PASFIELD, T., 24, Wellington Road, Dudley, Worcestershire.

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PATTERSON, J. R., Coal Creek Proprietary Company, Finks Buildings, Melbourne,
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 PRICE, S. WARREN, 25, Lochaber Street, Cardiff.
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 PROUT, JAMES, 16, Claremont Road, Redruth, Cornwall.
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- RIDLEY, N. B., 2, Collingwood Street, Newcastle-upon-Tyne.
- RIDSDALE, LANGFORD, Ingleside, Burton Road, Tamworth.
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- RIGBY, FRANK, Alsager, Stoke-upon-Trent.
- RITSON, J., Jun., 190, Warrington Road, Abram, Wigan.
- RITSON, U. A., 15, Queen Street, Newcastle-upon-Tyne.
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- ROBERTSON, W. M., 70, Great Clyde Street, Glasgow.
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- ROBSON, T. O., Chowdene Cottage, Low Fell, Gateshead-upon-Tyne.
- ROCHESTER, W., River View, Blaydon-upon-Tyne.
- ROGERS, D., Dudley Road, Tipton, Staffordshire.
- ROGERS, J. M., Wingfield House, Mount Hawk, near Scorrier, St. Agnes, Cornwall.
- ROLKER, C. M., Manager, Mining and Financial Trust Syndicate, Limited, 6, Drapers Gardens, London, E.C.
- ROME, J. E., 6, Roseburn Place, Edinburgh.
- RONALDSON, J. H., 40, Pitt Street, Sydney, New South Wales.
- RONALDSON, J. M., H.M. Inspector of Mines, 44, Athole Gardens, Glasgow.
- ROSCAMP, J., Shilbottle Colliery, Lesbury, R.S.O., Northumberland.
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- ROSS, J. A. G., 12, Regent Road, Gosforth, Newcastle-upon-Tyne.
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- ROUTLEDGE, JOSEPH.
- ROUTLEDGE, J. L., Waterloo Main Colliery, near Leeds.
- ROUTLEDGE, R., Garforth Colliery, Leeds.
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- ROWAN, HENRY, The Fife Coal Company, Limited, Hill of Beath, Crossgates, R.S.O., Fifeshire.
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 ROWBOTHAM, THOMAS, Shaw Villa, Stockport.
 ROWE, WILLIAM HENRY, 9, Earl Terrace, Douglas, Isle of Man.
 ROWLEY, WALTER, 20, Park Row, Leeds.
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 SANKEY, W. H., Morley Hall, Derby.
 SAWYER, A. R., 40, Brompton Square, London, S.W.; and P.O. Box 2233, Johannesburg, Transvaal.
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 SCHROLLER, WILLIAM, c/o Simon-Carves Bye-Product Coke Oven Construction and Working Company, Limited, 20, Mount Street, Manchester.
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 SECCOMBE, ALFRED F., 44, Hill Park Crescent, Plymouth.
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LIST OF MEMBERS.

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SENIOR, A., Birk House, Barnsley.
 SETTLE, JOEL, The Hill, Alsager, Stoke-upon-Trent.
 SETTLE, MILES, Darcy Lever Collieries, near Bolton.
 SETTLE, W., Darcy Lever Collieries, near Bolton.
 SKYMOUR, L. IRVING, P.O. Box 149, Johannesburg, Transvaal.
 SHARPE, GEORGE, 5, University Avenue, Partick, Glasgow.
 SHAW, F. G.
 SHAW, G., Wath Main Colliery, Rotherham.
 SHAW, JAMES, Stanley House, Kent Town, Adelaide, South Australia.
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 SHUTE, C. A., High Terrace, Darlington.
 SIDOLD, C. W., Public Works Department, Soane Circle, Arrah, Bengal, India.
 SIDEBOTHAM, J. N., 1, Princess Street, Albert Square, Manchester.
 SILVESTER, FRED., Newcastle, Staffordshire.
 SIMON, FRANK, P.O. Box 2986, Johannesburg, Transvaal.
 SIMPKIN, ARTHUR, South Kirkby, near Wakefield.
 SIMPKIN, J. W., Midsomer Norton, Bath.
 SIMPSON, C. L., Engine Works, Grosvenor Road, Pimlico, London.
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 SLADDEN, HARRY, P.O. Box 1666, Johannesburg, Transvaal.
 SLINN, T., Plashetts Colliery, Falstone, Northumberland.
 SLOOTEN, WILLIAM VAN, 52, Sidney Place, Brooklyn, New York, U.S.A.
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 SNEDDON, JAMES B., Oakbank Colliery, Mid-Calder, N.B.
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 SOUTHERN, T. A., 111, Rose Hill Street, Derby.
 SOUTHWORTH, THOMAS, Hindley Green Collieries, near Wigan.
 SPARGO, EDMUND, 3, Cable Street, Liverpool.
 SPARKES, J. S., 15, Northcote Street, Cardiff.
 SPEIRS, ADAM, Newliston Mine, Kirkliston, R.S.O., Linlithgowshire.
 SPENCE, FRANCIS JOSEPH, 94, South Terrace West, Adelaide, Australia.
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 SPENCER, E. D., 19, St. Peters Road, Leicester.
 SPENCER, F. H., Bonanza Gold Mining Company, P.O. Box 149, Johannesburg, Transvaal.
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 SPENCER, RICHARD, Hanover Square, Leeds.
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 SQUIRE, J. B., The Wynd, Streatham Park, London, S.W.
 STAFFORD, THOMAS W., King's Drive, Heaton Moor, Stockport.
 STALEY, A. H., 21, Coton Road, Nuneaton.
 STANDLEY, WILLIAM, Glenroy, Nuneaton.
 STANIER, FRANCIS, Peplow Hall, Salop.

- STANLEY, JAMES, 3, Chancery Chambers, Coolgardie, Western Australia.
 STANLEY, REGINALD, Stanley's Engineering Company, Nuneaton.
 STANSFELD, HAROLD SINCLAIR, High Hazels Colliery, Darnall, Sheffield.
 STANTON, JOHN, 11 and 13, William Street, New York, U.S.A.
 STANTON, PHILIP HARRISON, Hunley House, Brotton, R.S.O., Yorkshire.
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 STEPHENSON, G. R., Ben Braich, Tilehurst Road, Reading.
 STEVENS, A. J., Uskside Iron Works, Newport, Monmouthshire.
 STEVENS, JAMES, 9, Fenchurch Avenue, London, E.C.
 STEVENSON, HENRY, Hillside, Pinxton, Alfreton.
 STEVENSON, HUGH, 13, Carlton Place, Glasgow.
 STEVENSON, THOMAS, Earnock Colliery, Hamilton, N.B.
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 STOBES, J. T., 1, Seaton Terrace, Linthorpe Road, Middlesbrough.
 STOBBER, EDWARD G., P.O. Box 129, Silverton, Colorado, U.S.A.
 STOKER, ARTHUR P., Birtley, near Chester-le-Street.
 STOKER, HENRY, 5, Argyll Mount, Mansfield.
 STOKER, THOMAS E., Prospect House, Leasingthorne, Bishop Auckland.
 STOKES, JOHN, Tollcross Colliery, Tollcross, Glasgow.
 STONE, ARTHUR, Heath Villas, Hindley, Wigan.
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 STRAIN, HUGH, Cleddans, Easterhouse, Baillieston, Glasgow.
 STRAIN, JAMES M., 11, Hillend Gardens, Partickhill, Glasgow.
 STRAKER, J. H., Howden Dene, Corbridge-upon-Tyne.
 STREATFIELD, HUGH S., Ryhope, near Sunderland.
 STREET, JOHN, High Street, Silverdale, Newcastle, Staffordshire.
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 SWALLOW, J. F., Mosboro' Hill House, Eckington, Sheffield.
 SWALLOW, R. T., Simonside House, Simonside, South Shields.
 SWAN, H. F., North Jesmond, Newcastle-upon-Tyne.
 SWAN, J. G., Upsall Hall, near Middlesbrough.
 SWANN, HUGH P., Gartonaig, Shettleston, N.B.
 SYKES, FRANK K., Springwell Villa, Bishop Auckland.

- TATE, HENRY, Talk-o'-th'-Hill Colliery, Stoke-upon-Trent.
 TATE, SIMON, Trimdon Grange Colliery, Co. Durham.
 TATE, WILLIAM, Measham Main Colliery, Measham, near Atherstone.
 TATTLEY, WILLIAM, Taupiri Extended Coal Mining Company, Limited, Huntly,
 Waikato, New Zealand.
 TAYLOR, HUGH, East Holywell Office, Quayside, Newcastle-upon-Tyne.
 TAYLOR, JOHN HENRY, Borough Surveyor, Barnsley.
 TAYLOR, T., Quay, Newcastle-upon-Tyne.
 TEALE, W. E., Swinton, near Manchester.
 TEASDALE, T., Middridge, *via* Heighington, R.S.O.
 TELFER, HENRY, Birkhill, Uddingston, Glasgow.
 TELFORD, W. H., Hedley Hope Collieries, Tow Law, R.S.O., Co. Durham.
 TEMPERLEY, JOSEPH, Harriston, Aspatria, Carlisle.
 TERRIS, HENRY, Clackmannan Colliery, Clackmannan, Alloa, N.B.
 THACKTHWAITE, THOMAS MICHAEL, Beechfield, Farnham Royal, Bucks.
 THIRKELL, E. W., Oaks Colliery, Barnsley.
 THOM, JAMES R., Balbardie Colliery, Bathgate, N.B.
 THOMAS, J. J., Newnham Cottage, Kendal.
 THOMAS, R., Bloxwich, Walsall.
 THOMAS, R. G., 47, Talbot Terrace, Rugeley.
 THOMAS, W., Penelvan, Camborne, Cornwall.
 THOMLINSON, WILLIAM, Seaton Carew, R.S.O.
 THOMPSON, CHARLES LACY, Farlam Hall, Brampton Junction, Cumberland.
 THOMPSON, F. W., 15, Wood Street, Bolton, Lancashire.
 THOMPSON, JOHN G., Bamfurlong, Wigan.
 THOMPSON, THOMAS, Featherstone Main Collieries, Pontefract.
 THOMPSON, W., 58, New Broad Street, London, E.C.
 THOMSON, A. S., Brahmin Bararee, Jherriah P.O., District Manbhoom, Bengal,
 India.
 THOMSON, GEORGE, Bannockburn Colliery, Bannockburn, R.S.O., Stirlingshire.
 THOMSON, G. R., 204, George Street, Glasgow.
 THOMSON, JAMES, Ross Street, Dunfermline, N.B.
 THOMSON, JOHN, Glenarm Lime Works, Larne, Co. Antrim.
 THOMSON, JOHN, Easton Mines, by Middlesbrough.
 THOMSON, JOSEPH F., Manvers Main Colliery, Wath-upon-Deerne, Rotherham.
 THOMSON, RICHARD, Angle Cottage, Whifflet, Coatbridge, N.B.
 THOMSON, R. D., Ibstock Colliery, Leicester.
 THOMSON, THOMAS, Crossford, Dunfermline, N.B.
 THOMSON, THOMAS, Eddlewood Colliery, Hamilton, N.B.
 THORNEWILL, ROBERT, Engineering Works, Burton-upon-Trent.
 THORNEYCROFT, WALLACE, 25, Snowdon Place, Stirling, N.B.
 THORNTON, PETER, Crofthead Colliery, Fauldhouse, Linlithgowshire.
 TILLY, ALFRED, 12, Trewirgie, Redruth, Cornwall.
 TINKER, J. J., Hyde, Manchester.
 TODD, JOHN, Greenfield Terrace, Irvine, N.B.
 TODD, JOHN T., Blackwell Collieries, Alfreton.
 TODD, W. G., 69, Norfolk Road, Sheffield.
 TOMLINSON, JOHN, Acres, Pilsley, Chesterfield.
 TONKIN, J. J., Linares, Provincia de Jaen, Spain.
 TOUZEAU, E. M., Leadenhall Buildings, Leadenhall Street, London, E.C.
 TOWNSEND, HENRY GEORGE, St. John's Colliery, Normanton.
 TREADWELL, GEORGE A., Nevada City, California, U.S.A.

- TREGLOWN, C. H., 38, Wretham Road, Handsworth, Birmingham
 TRELEASE, W. HENWOOD, Pestarena United Gold Mining Company, Limited,
 Pestarena, Vall Anzasca, Novara, Italy.
 TRESTRAIL, N., Claremont Road, Redruth, Cornwall.
 TRUMP, FRED. J., Rhymney House, Rhymney, Monmouthshire.
 TURNBULL, A. W., 130, George Street, Edinburgh.
 TURNBULL, ROBERT, South Kirkby Colliery, Wakefield.
 TURNER, GEORGE, Buxton House, Holyhead Road, Handsworth, Birmingham.
 TURNER, JOHN, Moira Colliery, Ashby-de-la-Zouch.
 TURNER, SAMUEL, St. John's Colliery, Staveley, Chesterfield.
 TURNER, T. A., Aldwarke, Rotherham.
 TURNER, T. N., Langley Mill, Notts.
 TURNER, WILLIAM JEPSON, The Chase, Charnwood, Whitwick, Leicester.
 TYAS, A. R., Swaithe, near Barnsley.
 TYERS, JOHN E., Singareni Collieries, c/o Hyderabad Deccan Company, Limited,
 Secundarabad, Deccan, East India.
 TYZACK, DAVID, Sunwick, Chorlton-cum-Hardy.
- VALLANCE, WILLIAM, Ross Colliery, Ferniegair, Hamilton, N.B.
 VARTY, THOMAS, Skelton Park Mines, Skelton, R.S.O., Cleveland.
 VAUGHAN, CEDRIC, Hodbarrow Iron Ore Mines, Millom, Cumberland.
 VAUTIN, CLAUDE, Bevois House, 28, Basinghall Street, London, E.C.
 VEASEY, THOMAS FRED., 5, Copthall Buildings, London, E.C.
 VEASY, HARVEY C., Burrakur Coal Company, Limited, Barakar, Bengal, India.
 VEZIN, HENRY A., P.O. Box 256, Denver, Colorado, U.S.A.
 VIGGARS, BENJAMIN D., Hope Cottage, Downing Street, Silverdale, Staffordshire.
 VIGGARS, MATTHEW HENRY, Knutton Farm, Newcastle, Staffordshire.
 VITANOFF, GEORGE N., Sophia, Bulgaria.
 VIVIAN, JOHN, Vivian's Boring and Exploration Company, Limited, 42, Lowther
 Street, Whitehaven.
- WADDELL, ROBERT, 128, Onslow Drive, Glasgow.
 WADDLE, H., The Waddle Patent Fan and Engineering Company, Limited,
 Llanelly, South Wales.
 WADE, ROBERT ARMYTAGE, Linby Colliery, Nottingham.
 WADHAM, E., Millwood, Dalton-in-Furness.
 WADSWORTH, WILLIAM DEEAKIN, Jun., Newbold Road, Chesterfield.
 WAIN, EDWARD B., Whitfield Collieries, Norton-in-the-Moors, Stoke-upon-Trent.
 WAIN, J. R., Chatterley-Whitfield Collieries, Tunstall, Staffordshire.
 WAIN, WILLIAM HOLT, Cardiff Navigation Colliery, Llantrisant, Cardiff.
 WALDIE, JAMES F., 114, Bath Street, Glasgow.
 WALES, H. T., Pontypridd, South Wales.
 WALKER, DAVID, Jun., Oxcang, Kirkintilloch, N.B.
 WALKER, GEORGE BLAKE, Wharnccliffe Silkstone Colliery, Barnsley.
 WALKER, JAMES P., Ardoon, Dunaskin, Ayrshire.
 WALKER, J. S., Pagefield Iron Works, Wigan, Lancashire.
 WALKER JOHN W., Woodruff Cottage, Windmillhill Street, Motherwell, N.B.
 WALKER, PETER, 3, Tweed Street, West Calder, R.S.O., Midlothian.
 WALKER, SYDNEY F., Cardiff Electrical Works, Severn Road, Cardiff.
 WALKER, THOMAS A., Pagefield Iron Works, Wigan.
 WALKER, W., Hawthorns, Saltburn-by-the-Sea.
 WALKER, WILLIAM, Cadzow Colliery, Hamilton, N.B.

- WALKER, WILLIAM, Jun., H.M. Inspector of Mines, Durham.
 WALKER, W. E., Manners Colliery, Ilkeston.
 WALKER, WILLIAM EDWARD, Lowther Street, Whitehaven.
 WALKER, W. H., Springwells Colliery, Airdrie, N.B.
 WALL, HENRY, Rowbottom Square, Wallgate, Wigan.
 WALLACE, HENRY, Trench Hall, Gateshead-upon-Tyne.
 WALLACE, J., King Street, Wigan.
 WALLACE, JAMES, Wester Gartshore Colliery, Kirkintilloch, Glasgow.
 WALLAU, JACOB, 68, Coatsworth Road, Gateshead-upon-Tyne.
 WALLWORK, JESSE, Bolton Road, Atherton, Lancashire.
 WALSH, G. P., 564, Heirengracht, Amsterdam, Holland.
 WALTERS, HARGRAVE, Birley Collieries, Sheffield.
 WALTERS, J. T., Babbington Collieries, Nottingham.
 WALTON, J. COULTHARD, Writhlington Colliery, Radstock, *via* Bath.
 WALTON, THOMAS, Habergham Colliery, Burnley.
 WALTON, W. W., Croft Cottage, Ferryside, near Carmarthen, South Wales.
 WANLESS, BATEMAN, Garforth Colliery, Leeds.
 WAPLINGTON, WILLIAM, Glynacastle Collieries, Resolven, Neath.
 WARBURTON, J. S., 19, Stanwick Road, West Kensington, London, W.
 WARD, A. H., c/o Bengal Coal Company, Limited, Calcutta, India.
 WARD, F. L., Bradford Colliery, Bradford, Manchester.
 WARD, H., Rodbaston Hall, near Penkridge, Stafford.
 WARD, T. H., Kabribad, Giridih, E.I. Railway, Bengal, India.
 WARDELL, S. C., Doe Hill House, Alfreton.
 WARDLAW, JOHN, Stanley Cottage, Newmains, N.B.
 WARDLAW, ROBERT, Shiresmill, Newmills, Dunfermline, N.B.
 WARDLE, W., West Cannock Colliery, Hednesford, Staffordshire.
 WARING, G. W., 17, Grange Road, Dudley, Worcestershire.
 WARRINGTON, JAMES HENRY, Berry Hill Works, Stoke-upon-Trent.
 WASHINGTON, W., Hawthorn Cottage, Wombwell, Barnsley.
 WATERHOUSE, M. W., Glass Houghton Colliery, Castleford.
 WATKYN-THOMAS, W., Workington.
 WATSON, ADAM, c/o Blane and Company, P.O. Box 435, Johannesburg, Transvaal.
 WATSON, ANDREW, Cadzow Colliery, Hamilton, N.B.
 WATSON, EDWARD, South Pelaw Colliery, Chester-le-Street.
 WATSON, Sir JOHN, Bart., Earnock, Hamilton, N.B.
 WATSON, JOHN, Lancaster Gold Mining Company, Limited, P.O. Box 144, Krugersdorp, South African Republic.
 WATSON, JOHN G., Ivy Bank, Armadale Station, Linlithgowshire. Transactions to be sent to Mrs. Watson, 7, Church Road, Bellahouston, Glasgow.
 WATSON, SIMEON, New Hucknall Colliery, Mansfield.
 WATSON, T., Trimdon Colliery, Trimdon Grange.
 WATSON, WILLIAM, Annesley, Uddingston, Glasgow.
 WATSON, WILLIAM, Livingstone Terrace, Uddingston, Glasgow.
 WATTS, JOHN, Mossfield Colliery, Longton, Staffordshire.
 WATTS, J. WHIDBOURNE, General Manager, United Ivy Gold Mining Company, Barberton, Transvaal.
 WATTS, WILLIAM, Piethorn, near Rochdale.
 WAUCHOPE, J. A., Auckland, New Zealand.
 WEBSTER, DAVID, Burdiehouse Limeworks, Loanhead, Midlothian.
 WEBSTER, H. INGHAM, Mainsforth Hall, Ferry Hill, S.O., Co. Durham.
 WEBSTER, JOHN.

- WEEKS, J. G., Bedlington, R.S.O., Northumberland.
 WEEKS, R. L., Willington, Co. Durham.
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 WELCH, DAVID WILLIAM, Dixie Gold Mines, Limited, Black Flag, Western
 Australia.
 WELLS, W. E., Eckington Collieries, Sheffield.
 WEMYSS, R. E., Wemyss Castle, Fifeshire.
 WESTERN, C. R., Broadway Chambers, Westminster, London, S.W.
 WHEATLEY, SAMUEL, Nailstone Colliery, Leicestershire.
 WHITE, ANDREW, Ormiston Colliery, Ormiston, N.B.
 WHITE, C. E., Wellington Terrace, South Shields.
 WHITE, GEORGE, Estate Office, Mexboro', near Rotherham.
 WHITE, H., Walker Colliery, Newcastle-upon-Tyne.
 WHITE, H. BARTLETT, Princess Estate and Gold Mining Company, Limited,
 General Manager's Office, P.O., Roodepoort, Transvaal.
 WHITE, I. W. H., 1, Albion Place, Leeds.
 WHITE, J. F., 15, Wentworth Street, Wakefield.
 *WHITEHEAD, JAMES, Brindle Lodge, near Preston, Lancashire. Transactions
 to be sent to Thomas Whitehead, Brindle Lodge, near Preston, Lancashire.
 WHITEHEAD, JOHN, Ashleigh, Buxton.
 WHITEHEAD, JOHN JAMES, Bracklyn, Stretford, Manchester.
 WHITEHOUSE, W. H., Brownhills, Walsall.
 WHITELAW, JOHN, 118, George Street, Edinburgh.
 WHITELAW, THOMAS, 112, Wellington Street, Glasgow.
 WHITESIDE, JOHN, The Bothwell Coal Company, Limited, Holytown, N.B.
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 WHYTE, ROBERT, Clyde Wire Rope Works, Rutherglen, Glasgow.
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 WIGHT, W. H., Cowpen Colliery, Blyth.
 WILCOX, H., Miners' Safety Explosive Works, Stanford-le-Hope, Essex.
 WILDE, W., Rockingham Colliery, Barnsley.
 WILDE, WILLIAM, Brockett House, Sharrow, Sheffield.
 WILKES, JOHN S., Pelsall Foundry, Walsall.
 WILKIE, NEIL A., Nethercroft Mines, Croy, Glasgow.
 WILKINSON, J. R., Spark Lane, Mapplewell, Barnsley.
 WILKINSON, THOMAS, Tinsley, near Sheffield.
 WILKINSON, WILLIAM FISCHER, Rand Club, Johannesburg, Transvaal.
 WILKS, ARTHUR, Batmans Hill House, Bradley, Bilston.
 WILLIAMS, EDMUND W., Henahall House, Goldenhill, Stoke-upon-Trent.
 WILLIAMS, ERNEST, c/o Bewick, Moreing and Company, A.M.P. Buildings,
 St. George's Terrace, Perth, Western Australia.
 WILLIAMS, GARDNER F., De Beers Consolidated Mines, Limited, Kimberley,
 South Africa.
 WILLIAMS, HERBERT IGNATIUS, The Old Rectory, Scholar Green, Cheshire.
 WILLIAMS, H. J. CARNEGIE, c/o J. McDonald, 43, Threadneedle Street, London,
 E.C.
 WILLIAMS, J., 115, Wellington Road, Dudley, Worcestershire.
 WILLIAMS, R., The Johnson's Reef Gold Mines Company, N.L., California
 Gully, Bendigo, Victoria, Australia.

- WILLIAMS, ROBERT, 30, Clements Lane, Lombard Street, London, E.C.
 WILLIAMS, SAMUEL HERBERT, Golden Cement Claims, Limited, Kanowna,
 Western Australia.
 WILLIAMSON, J., The Hills, Cannock, Staffordshire.
 WILLIAMSON, J. H., Henshall House, Goldenhill, Stoke-upon-Trent.
 WILLIAMSON, R., Park Hill Colliery, Wakefield.
 WILLIAMSON, R. S., Cannock Wood House, Hednesford, Staffordshire.
 WILLIAMSON, THOMAS, West Hallam Collieries, Ilkeston.
 WILLIAMSON, WILLIAM, Opal Cottage, Burnblea, Hamilton, N.B.
 WILLIAMSON, W. DUNCAN, c/o John Williamson, Cumberland Cyanide Works,
 Cumberland, North Queensland.
 WILSON, BENJAMIN.
 WILSON, DAVID, 46, Jarvey Street, Bathgate, N.B.
 WILSON, GEORGE, Blairadam Colliery, Kelty, Fifeshire.
 WILSON, JOHN, 75, Bothwell Street, Glasgow.
 WILSON, J. B., Wingfield Iron Works and Colliery, Alfreton.
 WILSON, JOHN R. ROBINSON, H.M. Inspector of Mines, 1, St. Mary's Road,
 Newton Park, Leeds.
 WILSON, JOSEPH M., St. John's Colliery, Normanton.
 WILSON, LLOYD, Flimby Colliery, Maryport.
 WILSON, P. O., Klerksdorp, South Africa.
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 WILSON, W. B., Thornley Colliery, Thornley, R.S.O., Co. Durham.
 WILSON, W. E. C., Shipley Collieries, Derby.
 WINCHELL, HORACE V., 1306, S.E. 7th Street, Minneapolis, Minnesota, U.S.A.
 WINGATE, JOHN B., 208, St. Vincent Street, Glasgow.
 WINSTANLEY, PETER, Shaw Cross Colliery, near Dewsbury.
 WINSTANLEY, ROBERT, 28, Deansgate, Manchester.
 WINTER, T. B., Grey Street, Newcastle-upon-Tyne.
 WITHERS, CHARLES, 65, Station Street, Nottingham.
 WITTY, H. SYKES, Denaby Main House, near Rotherham.
 WOLSTENHOLME, M., Llanfoist House, near Abergavenny.
 WOOD, C. L., Freeland, Forgandenny, Perthshire.
 WOOD, E. S., c/o Bengal Coal Company, Old Court House Street, Calcutta,
 India.
 WOOD, JAMES, 28, Royal Exchange Square, Glasgow.
 WOOD, JOHN, Coxhoe Hall, Coxhoe, R.S.O., Co. Durham.
 WOOD, JNO., Barley Brook Foundry, Wigan.
 WOOD, SIR LINDSAY, Bart., The Hermitage, Chester-le-Street.
 WOOD, THOMAS.
 WOOD, THOMAS, North Hetton Colliery Office, Moorsley, Hetton-le-Hole, R.S.O.
 WOOD, W. H., Coxhoe Hall, Coxhoe, Co. Durham.
 WOOD, WALTER K., Broomhouse Colliery, Broomhouse, Glasgow.
 WOOD, W. O., South Hetton, Sunderland.
 WOODBURN, J. ALLAN, Lydenburg (Transvaal) Gold Exploration Company,
 Limited, Pilgrims Rest, South African Republic.
 WOODBURN, T. J., De Beers Consolidated Mining Company, Limited, Kimberley,
 South Africa.
 WOODHEAD, ALFRED, Low Moor Iron Works, Bradford.
 WOODHEAD, L., Beeston Colliery, Leeds.
 WOODS, RICHARD, Seymour Colliery, Staveley, Chesterfield.

- WOODWARD, HARRY P., 59, Irwin Street, Perth, Western Australia. Transactions, etc., to be addressed to 129, Beaufort Street, Chelsea, London, S.W.
- WOODWORTH, BENJAMIN, Heron Cross, Fenton, Stoke-upon-Trent.
- WOOLCOCK, J. H., 49, Lowther Street, Whitehaven.
- WORDSWORTH, ROBERT, Warora Colliery, Central Provinces, India.
- WORDSWORTH, T. H., New Moss Colliery, Audenshaw, near Manchester.
- WORMALD, C. F., Mayfield Villa, Saltwell, Gateshead-upon-Tyne.
- WORTH, F. G., 63, Queen Victoria Street, London, E.C.
- WRIGHT, HENRY, Coolgardie, Western Australia.
- WRIGHT, JOSEPH, Arboretum Street, Nottingham.
- WRIGHTSON, T., Stockton-upon-Tees.
- WROE, JAMES, Sutton Colliery, Mansfield, Notts.
- WROE, JONATHAN, Wharnccliffe Silkstone Colliery, Barnsley.
- WYNNE, T. TRAFFORD.
- WYPER, JAMES, Townlands Colliery, Hamilton, N.B.
- WYSEHALL, GEORGE E., Kaiping Mines, c/o H.B.M. Consulate, Tientsin, North China.
- YATES, JOHN, Per Private Bag, Glencairn Gold Mining Company, Limited, Germiston, Johannesburg, Transvaal.
- YEOMAN, THOMAS P., Manager, Bengal Coal Company's Collieries, Lalkdih, *via* Barakar, E.I.R., Bengal, India.
- YOUNG, HENRY WILLIAM, Greymouth, New Zealand.
- YOUNG, JOHN, Baljaffray Colliery, Bearsden, Glasgow.
- YOUNG, JOHN, The British Gas Light Company, Limited, Etruria, Stoke-upon-Trent.
- YOUNG, JOHN A., 3, Fountain Avenue, Gateshead-upon-Tyne.
- YOUNG, J. H., Wearmouth Colliery, Sunderland.
- YOUNG, ROBERT, Tacoma, Washington, U.S.A.
- YOUNG, WILLIAM ALEXANDER, 16, St. Helen's Place, London, E.C.
- ZUMBULOGLOU, G. C., Mahmoudie-Han, Stamboul, Turkey

Associate Members.

* Deceased.

- AINSWORTH, HARRY S., "Belvedere," Marine Terrace, Geraldton, Western Australia.
- ANDERSON, J. SCOTT, 53, Waterloo Street, Glasgow.
- APPLEYARD, HENRY, c/o W. Firth, Water Lane, Leeds.
- ARMSTRONG, J. H., St. Nicholas' Chambers, Newcastle-upon-Tyne.
- ARMSTRONG, T. J., Hawthorn Terrace, Newcastle-upon-Tyne.
- ATKINSON, G. B., Prudential Assurance Buildings, Mosley Street, Newcastle-upon-Tyne.
- AUDUS, T., Mineral Traffic Manager, North Eastern Railway, Newcastle-upon-Tyne.
- BACKHOUSE, THOMAS SALMON, 42 and 43, Pirie Chambers, Adelaide, South Australia.
- BAGSHAW, F., 4, Ash Grove, Headingley, Leeds.

- BARR, THOMAS H., 10, Bothwell Street, Glasgow.
 BELL, HUGH, Middlesbrough-upon-Tees.
 BENEKÉ, GEORGE, 70, Gracechurch Street, London, E.C.
 BENSON, PETER, 69, Buchanan Street, Glasgow.
 BIGGE, EDWARD ELLISON, General Mining Association, Dashwood House, 9, New Broad Street, London, E.C. Transactions, etc., to be sent to R. H. Brown, Sydney Mines, Cape Breton, Nova Scotia.
 BLENKIRON, J. E., Zomba, British Central Africa.
 BLUE, A., Bureau of Mines, Toronto, Ontario, Canada.
 BREE, JOHN, Bleak House, Litlington, near Royston, Herts.
 BROTHERS, HORACE EDWARD, Park Terrace, Tunstall, Staffordshire.
 BURDON, A. E., Hartford House, Cramlington, Northumberland.
- CAPELL, Rev. G. M., Passenham Rectory, Stony Stratford.
 CARR, WILLIAM COCHRAN, 91, Jesmond Road, Newcastle-upon-Tyne.
 CHAPLIN, GEORGE P., 124, Breakspears Road, Brockley, London, S.E.
 CHAPMAN, C. W., The Australian Smelting Company, Limited, 372, Flinders Lane, Melbourne, Australia.
 CHEWINGS, CHARLES, Albany, Western Australia.
 CLELAND, E. DAVENPORT, Bayley Street, Coolgardie, Western Australia.
 COCHRANE, R. D., Hetton Colliery Offices, Fence Houses.
 COCKBURN, W. C., St. Nicholas' Buildings, Newcastle-upon-Tyne.
 COLQUHOUN, A. J., School of Mines, Vancouver, British Columbia.
 COOPER, R. W., Newcastle-upon-Tyne.
 COURT, JOSIAH, Staveley, Chesterfield.
 COX, PERCY MOTTRAM, Stoke-upon-Trent.
- DAVENPORT, J. E., The Elms, Oulton, Leeds.
 DUIGNAN, W. H., Gorway House, Walsall.
 DUNCAN, G. T., 96, Brighton Grove, Newcastle-upon-Tyne.
 DUNSTON, GEORGE, Hatfield Grange, Doncaster.
- EGGLEES, EDWARD, King Street, Newcastle-upon-Tyne.
 EDWARDS, F. H., Forth House, Bewick Street, Newcastle-upon-Tyne.
 ELLAM, ALBERT SPENCER, 20, Bucklersbury, London, E.C.
- FERGUSON, C. A., 41, Lovaine Place, Newcastle-upon-Tyne.
 FINDLAY, MATTHEW F., 41, Ann Street, Glasgow.
 FIRTH, JOHN G., Hunslet New Road, Leeds.
 FIRTH, WILLIAM, Water Lane, Leeds.
 FOSTER, T. J., Coal Exchange, Scranton, Pennsylvania, U.S.A.
- GOODLAND, GILLMORE, Ravenswood, Queensland, Australia.
 GRIFFIN, NOEL, Geelong Gold Mines, Gwanda, Matabeleland, South Africa.
 GUE, T. R., P.O. Box 520, Halifax, Nova Scotia.
 GUTHRIE, REGINALD, Neville Hall, Newcastle-upon-Tyne.
 GWYN, A. E. W., 114A, Queen Victoria Street, London, E.C.
- HARDY, THOMAS EDWARD, Kalgoorlie, Western Australia.
 HARVEY, FRANCIS G., Plu le Desir, Canal No. 1, Demarara, British Guiana.
 HEDLEY, E., Rainham Lodge, The Avenue, Beckenham, Kent.
 HEDLEY, J. HUNT, John Street, Sunderland.

HENLEY, GEORGE, 43, Harcourt Road, Sheffield.
HENDERSON, C. W. C., The Riding, Hexham.
HENZELL, ROBERT, Prudential Buildings, Mosley Street, Newcastle-upon-Tyne.
HEPPELL, W. J., Cwmaman Colliery, Aberdare, South Wales.
HEYWORTH, Colonel LAWRENCE, Chadacre Hall, Bury St. Edmunds, Suffolk.
HICKMAN, E., Stone Quarries, Bilston.
HODGSON, ALBERT, P.O. Box 212, Buluwayo, Rhodesia, South Africa.
HOLLAND, WILLIAMSON, 65, William Street, Heywood, Lancashire.
HOFFER, J. L., Wire Rope Works, Thornaby-upon-Tees.
HUMPHREYS-DAVIES, G., 8, Laurence Pountney Hill, Cannon Street, London, E.C.
HUNTER, C. E., Selaby Park, Darlington.

I'ANSON, JAMES, Fairfield House, Darlington.
INGOLD, HERBERT, c/o W. Cooke and Company, Limited, Tinsley Steel and Iron Works, Sheffield.
IRVINE, J. R., Hendon Ropery, Sunderland.

JAMES, H. M., Colliery Office, Whitehaven.
JOICEY, JAMES JOHN, Holyrood, Laurie Park Road, Sydenham, London, S.E.

KENNEDY, GEORGE THOMAS, Kings College, Windsor (Hants County), Nova Scotia.
KIRKUP, FRED. O., Langley Park, Durham.
KROHN, H. A., 103, Cannon Street, London, E.C.

LARSEN, A., 22, Austin Friars, London, E.C.
LOEY, J., P.O. Box 778, Johannesburg, Transvaal.
LOWLES, JOHN I., 165, Fenchurch Street, London, E.C.

MARSHALL, P., College and Grammar School, Auckland, New Zealand.
McLAREN, J. GORDON, 165, Fenchurch Street, London, E.C.
MIDDLETON, R. J., 15, Balfour Road, Highbury, London, N.
MONCKTON, G. F., School of Mines, Vancouver, British Columbia.

PALMER, A. M., 14, Windsor Terrace, Newcastle-upon-Tyne. Transactions to be sent to the Secretary, Anglo-American Club, Freiberg, Saxony, Germany.
PEARSON, ALFRED, Estate Office, Dukinfield, Manchester.
PEASE, ARTHUR, 92, Northgate, Darlington.
PERKINS, CHARLES, Middleton Hall, Belford, Northumberland.
PRINGLE, JOHN, Chinese Engineering Company, Tong Shang Colliery, Tientsin, North China.
PROCTOR, J. H., 22, Hawthorn Terrace, Newcastle-upon-Tyne.

RICHTER, F., Osborne Villas, Newcastle-upon-Tyne.
RIDLEY, J. C., 3, Summerhill Grove, Newcastle-upon-Tyne.
RIDLEY, Sir MATTHEW WHITE, Bart., Blagdon, Northumberland.
RITSON, J. R., Burnhope Colliery, Lanchester.
ROBINSON, J. WALTON, 6, Gladstone Terrace, Gateshead-upon-Tyne.
ROBSON, H. N., Post Office, Honolulu, Hawaiian Islands.
ROGERSON, JOHN E., Oswald House, Durham.

- SAUNDERS, G. B., c/o Saunders, Todd and Company, Maritime Buildings, King Street, Newcastle-upon-Tyne.
- SHAW, SAVILLE, Durham College of Science, Newcastle-upon-Tyne.
- SHERLAW, JAMES LINN, Coolgardie Gold Syndicate, Coolgardie, Western Australia.
- SJÖGREN, HJ., Osmo-Nynas, Sweden.
- SMITH, C. A., 20, Alexandra Place, Newcastle-upon-Tyne.
- SMITH, CLARENCE D., 11, Queen Street, Newcastle-upon-Tyne.
- SMITH, PERCY WEBSTER, Crichtons, Romford, Essex.
- SNOWBALL, FRANCIS JOHN, Seaton Burn House, Dudley, Northumberland.
- STANDRING, P. W. D., Strafford Collieries, Barnsley.
- SWINBURNE, U. P., c/o Richard Chamberlain, 39, Cadogan Square, London, S W.
- TAYLOR, J. HOWARD, Coolgardie, Western Australia.
- THOM, JOHN, Canal Works, Patricroft, near Manchester.
- THOMPSON, EDWARD, 38, Melton Road, West Bridgford, Nottingham.
- TIMES, HENRY, 85, London Wall, London, E.C.
- TODD, JAMES, Elvet Bridge, Durham.
- TURNER, BASIL WILLIAM, 40, Collins Street, Annandale, Sydney, New South Wales.
- WAINES, EDGAR W., Werrington, Stoke-upon-Trent.
- WALL, G. YOUNG, Halmote Court Office, New Exchequer Buildings, Durham.
- WALMESLEY, OSWALD, 2, Stone Buildings, Lincoln's Inn, London, W.C.
- WARD, JOHN, Stafford Street, Longton, Staffordshire.
- WATSON, ARTHUR, Whittington, Corbridge-upon-Tyne.
- WEATHERBURN, J., 199, Saltwell Road, Gateshead-upon-Tyne.
- WEDGWOOD, LEVESON, North Road, Corbridge, Stoke-upon-Trent.
- WEHNER, FRED. C., c/o Senor Don Carlos Wagner, Arequipa, Peru.
- WILLIAMS, THOMAS, Halesowen.
- WILLS, LOUIS, Coolgardie, Western Australia.
- WILSON, A. P., Mansion House Chambers, Queen Victoria Street, London, E.C.
- WOOD, ARTHUR NICHOLAS LINDSAY, The Hermitage, Chester-le-Street.
- WOOD, E. P., Lynher Villa, Crafthole, St. Germans, Cornwall.

Associates.

* Deceased.

- AUSTIN, T. W., Roundwood Colliery, Parkgate, Rotherham.
- BAILEY, J. H., New Buildings, Dordon, Tamworth.
- BAINBRIDGE, J., North Walbottle Colliery, Newcastle-upon-Tyne.
- BAKER, GEORGE, Bedlington Colliery, Bedlington, R.S.O.
- BAKER, JAMES L., Randfontein Estates, Limited, Randfontein, South African Republic.
- BALL, JOSEPH, Taquah Gold Mine, Axim, Gold Coast, West Africa.
- BALL, JOSIAH, Teversal Collieries, Mansfield.
- BARBER, JOSEPH, Ansley Hall Colliery, Atherstone.
- BARRESS, M., Tudhoe Colliery, Spennymoor.
- BATTEY, THOMAS, Percy Terrace, Backworth Colliery.
- BEDFORD, A., Warren Drive, Shirebrook, Mansfield.

- BELL, J., Wardley Colliery, Newcastle-upon-Tyne.
BELL, W. R., Wearmouth Colliery, Sunderland.
BENTLEY, GEORGE, Bradford Colliery, Manchester.
BERRY, THOMAS, 1, Middleton, Swalwell, R.S.O.
BEWICK, GEORGE, Dudley Colliery, Northumberland.
BLAIR, JOHN, Whitebarn Colliery, Newcastle, Staffordshire.
BLAIR, HENRY, Steel's Lane, Brimington Common, Chesterfield.
BLOOD, JOHN, Bentinck Houses, Kirkby in Ashfield, Nottingham.
BOLAM, J. T., The View, Beamish, Chester-le-Street.
BOOTH, AARON, Hilcote, Blackwell, Alfreton.
BOWES, THOMAS, Pontop House, Annfield Plain, R.S.O.
BOWMAN, FRANK, Auckland Park Colliery, near Bishop Auckland.
BRAMLEY, WILLIAM, Dale Moor, Ilkeston.
BRIGGS, JOHN, Church Street, Eckington, Sheffield.
BROWN, JOHN.
BROWN, R. O., Throckley Colliery, near Newcastle-upon-Tyne.
BURDETT, J. C., Midway, Swadlincote, Burton-upon-Trent.
BUTTERWORTH, GEORGE, Egstow, Market Street, Clay Cross, Chesterfield.
BUXTON, SIMEON, Wood Street, Church Gresley, Burton-upon-Trent.
- CHAMBERS, JAMES.
CLAMP, ELLIAH, Birch Coppice Colliery, near Tamworth.
CLARE, HENRY, Birchenwood Colliery Company, Limited, Kildagrove, Stoke-upon-Trent.
CLARK, THOMAS, Dipton Colliery, Lintz Green Station.
CLAY, ZECHARIAH, New Watnall, Nottingham.
CLIFFORD, E. HERBERT, c/o W. Y. Campbell, P.O. Box 357, Johannesburg, Transvaal.
CLOUGH, JOHN, 1, Melton Terrace, Seaton Delaval, R.S.O., Northumberland.
COCKBURN, EVAN, Page Bank Colliery, via Spennymoor, Durham.
COLLINS, W. F.
COUPE, ROBERT, Tibshelf Colliery, Alfreton.
COWELL, J. S., Wearmouth Colliery, Sunderland.
COWX, H. F., Thornley Collieries, via Trimdon Grange, R.S.O.
CROWN, WILLIAM, 39, Fifth Row, Ashington, Morpeth.
CUTTS, GEORGE, Lowes Hill, Ripley, Derby.
- DAVIES, SAMUEL, Barrow Farm, Worsborough, near Barnsley.
DAVIS, THOMAS, New Higham, Alfreton.
DAY, JAMES, Clown, Chesterfield.
DAYKIN, GEORGE, 31, High Gurney Villa, near Bishop Auckland.
DIXON, JOSEPH A., 115, Ravensworth Road, Dunston-upon-Tyne.
DORMAND, RALPH B., Waldrige Colliery, Chester-le-Street.
DOWNING, JOHN, Bedworth, Nuneaton.
DRAPER, W., New Seaham Colliery, Sunderland.
DRAYCOTT, JOSEPH, Alfreton Colliery, Alfreton.
DUNNETT, SAMUEL, Cambois Colliery, Northumberland.
- ELLIOTT, DANIEL, Houghton Main Colliery, Barnsley.
ELLIOTT, J. W., Kirkby Colliery, Kirkby-in-Ashfield, Nottingham.
ELTRINGHAM, GEORGE, Eltringham Colliery, Prudhoe-upon-Tyne, R.S.O.
ELVES, EDWARD, Middridge Colliery, Heighington, R.S.O.
EVANS, WILLIAM, Cliffe Vale, Stoke-upon-Trent.

FAIRS, JOHN, 35 and 37, Laygate Lane, South Shields.
 FAWCETT, EDWARD, 27, Eastbourne Gardens, Walker-upon-Tyne.
 FERGUSON, KENNETH, c/o Charles Cammel and Company, Limited, Cyclops Works, Sheffield.
 FEWSTER, JOHN, Coldwell House, Felling, R.S.O., Co. Durham.
 FINCH, W. W., The Lewdin Colliery Company, Worsborough Dale, Barnsley.
 FISHER, ARTHUR, 160, Ashton New Road, Clayton, Manchester.
 FORSTER, J. H. B., Cramlington Colliery, Northumberland.
 FOSTER, J. W., Whitburn Colliery, South Shields.
 FOSTER, THOMAS, Oaks Colliery House, near Barnaley.
 FOULSTONE, H., Borough Foundry, Barnaley.

GORDON, G. S., 24, Louisa Terrace, Stanley, R.S.O., *via* Chester-le-Street.
 GRAY, W. J., Birley Collieries, Sheffield.
 GREENE, JOHN, Priors Lee, Shifnal, Shropshire.
 GRIFFIN, GEORGE, Parkside, Market Street, Clay Cross, Chesterfield.

HADLEY, WILLIAM, Shelton Steel and Iron Company, Stoke-upon-Trent.
 HALBAUM, H. W., Allerdene, Lamesley, Gateshead-upon-Tyne.
 HALL, GEORGE, Broomhall Villa, Broomhall Park, Old Whittington, Chesterfield.
 HABLE, R. A., Wallsend Colliery, Wallsend-upon-Tyne.
 HARRISON, GEORGE, High Park Colliery, Greasley, Nottingham.
 HEATH, A. S., Adderley Green Collieries, Stoke-upon-Trent.
 HEDLEY, A. M., Medomaley, R.S.O., Co. Durham.
 HENDERSON, WILLIAM, Wheatley Hill Colliery, *via* Trimdon Grange.
 HENRY, JAMES, Howgill Staith, Whitehaven.
 HENSHAW, JOHN, Butterley Park, Butterley, Derby.
 *HEPBURN, T., The Firs, Langley Park, Durham. Transactions to be sent to Wheldon Hepburn, Littleton Colliery, near Durham.
 HERRON, EDWARD, 4, Holly Terrace, Stanley, R.S.O.
 HESLINGTON, ALFRED, Danesmoor, Clay Cross, Chesterfield.
 HEWITT, JOSEPH, Heron Cross, Fenton, Stoke-upon-Trent.
 HILL, ROBERT, Norton Colliery, Smallthorne, Burslem, Staffordshire.
 HILL, WILLIAM, Manor Street Foundry, Fenton, Stoke-upon-Trent.
 HINDMARCH, JOHN, Isabella Pit, Newsham, Blyth.
 HOBSON, JOHN, Crigglestone, Wakefield.
 HOBSON, MOSES, Shildon, *via* Darlington.
 HODGSON, E., Black Boy Colliery, Bishop Auckland.
 HODSON, JAMES E., Furnace Road, Normacot, Stoke-upon-Trent.
 HUGHES, A. E., Lea Terrace, Union Road, Newhall, Burton-upon-Trent.
 HUGHES, WILLIAM, Springwood, Chesterton, Staffordshire.
 HULETT, CHARLES T., Lilleshall Collieries, St. Georges, Wellington, Salop.
 HUNTER, A., 4, Davidson Terrace, Felling-upon-Tyne.
 HUNTER, CHRISTOPHER, 18, Stanley Street, Blyth, Northumberland.

JAMES, A. A., Croxdale, near Durham.
 JENKINS, J. P., 135, White Lea Road, Swinton, Yorkshire.
 JEPSON, W. W., Mexboro' House, Selston, Alfreton.
 JOHNSON, WILLIAM, Framwellgate Moor, Durham.

KEELING, FRANCIS, Newcastle Colliery, Nottingham.
 KENYON, G. C., 13, Fitzwilliam Street, Wath-upon-Deane, Rotherham .

- KIRK, SAMUEL, Colliery Yard, Cinderhill, Nottingham.
 KNIGHT, JOHN L., Adderley Green Collieries, Stoke-upon-Trent.
 KNIGHTON, HERBERT, High Park, Newthorpe, Notts.
- LAMBERT, R. W., Dolphin Hotel, Mushroom Lane, Sheffield.
 LEBETER, ROBERT, Dordon, Tamworth.
 LEE, JOHN, Whitfield Collieries, Norton-in-the-Moors, Stoke-upon-Trent.
 LIGHTLEY, JOHN, Front Street, Sherburn Colliery, Durham.
 LINDAY, ROBERT, 3, Sebastopol Terrace, Seaham Harbour.
 LINNEKER, J. G., Creswell, near Mansfield.
 LISHMAN, T. A., South Wingfield Colliery Company, Limited, Alfreton, Derbyshire.
 LISTER, R. L., Charity Collieries, Bedworth, Nuneaton.
 LITTLEJOHN, ALBERT, Mount Kembla Colliery, Wollongong, New South Wales.
 LOCKETT, WILLIAM, West View, Park Road, Burslem, Staffordshire.
 LONGDON, ALBERT, Newthorpe, Notts.
 LONGSDALE, NIGEL, Harecastle and Woodshutts Colliery, Stoke-upon-Trent.
 LOVE, WILLIAM ALLEN, Cornsay Colliery, Co. Durham.
- MACHIN, THOMAS, Teversal, Mansfield.
 MACINTOSH, T., Watts Farm, Blyth.
 MACKINLAY, E., 20, Fourth Street, Heworth Village, Felling, R.S.O., Co. Durham.
- MANDERSON, JOHN TOM, Seaton Delaval Colliery, R.S.O., Northumberland.
 MARR, JAMES HEPPEL, Leaffield House, Chester-le-Street.
 MASCALL, W. H., Joanroyd Colliery, Heckmondwike.
 MASON, BENJAMIN, Burnopfield Colliery, Burnopfield, R.S.O., Durham.
 MEAKIN, JOSEPH, Mansfield Road, Eastwood, Notts.
 MILBURN, WILLIAM, Cornsay House, Cornsay, Durham.
 MILLER, ALEXANDER, Niddrie Cottages, Portobello, N.B.
 MILLER, J. H., South Hetton, Sunderland.
 MILLESHIP, J. H., Watnall Colliery, Watnall, Notts.
 MINNIKIN, JOHN, Ivy Cottages, Hoyland Common, Barnsley.
 MINTO, GEORGE W., 2, Chapel Row, Ouston, Chester-le-Street.
 MORBY, W., Ardyngnook, West Lane, Baildon, Yorkshire.
 MORGAN, THOMAS, Hall End Colliery, near Tamworth.
 MOSS, HENRY, 223, Derby Road, Nottingham.
 MOULTON, LEVI, The Villas, Silverdale, Staffordshire.
 MUIRHEAD, JAMES.
 MULLINS, WILLIAM, Bishop Street, Eastwood, Notts.
- NAISBIT, JOHN, 48, Tudhoe Colliery, Spennymoor.
 NAYLOR, GEORGE E.
 NICHOLSON, A. D., 14, Chatsworth Square, Carlisle.
 NUTTALL, G. H., 97, Craven Road, Darnall, Sheffield.
- PARKER, HENRY, Godley Brook, Dilhorne, Stoke-upon-Trent.
 PARKINSON, W., 6, Ivy Terrace, South Moor, Chester-le-Street.
 PATRICK, J. A., West Pool Villas, Saltergate, Chesterfield.
 PEASEGOOD, W. G., Leycett, Newcastle, Staffordshire.
 PEDELTY, SIMON, Clara Vale, Ryton-upon-Tyne.
 PERCIVAL, JOSEPH, Netherseal Colliery, Burton-upon-Trent.

PERCY, R. F., 76, Belvoir Crescent, Sneinton, Nottingham.
 PRATT, G. ROSS, Springwell Colliery, Gateshead-upon-Tyne.
 PRATT, MILES, 33, Black Boy, *via* Bishop Auckland.
 PROCTOR, THOMAS, Ashington Colliery, Northumberland.
 PUGHE, W. A., Mellor Vicarage, Blackburn, Lancashire.

RAMSAY, JOHN, Tursdale Colliery, Ferryhill.
 RAMSAY, J. G., Page Bank Colliery, *via* Spennymoor, Co. Durham.
 RAMSDEN, E., Crigglestone, Wakefield.
 RATOLIFFE, WILLIAM, Beazley View, Chesterton, Newcastle, Staffordshire.
 RAWSON, GEORGE, Tibshelf, Alfreton.
 RHODES, J. H., Upper Pleasley, Mansfield.
 RIDLEY, G. D., Tudhoe Colliery, Spennymoor.
 RIVERS, JOHN, Bow Street, Thornley Colliery, Durham.
 ROBERTS, THOMAS, Brownhills Colliery, Tunstall, Staffordshire.
 ROBINSON, GEORGE HERBERT, Jubilee Chambers, Station Road, Tunstall, Stoke-upon-Trent.
 ROBINSON, GEORGE L., Trentham Road, Dresden, Longton, Staffordshire.
 ROBINSON, WILLIAM, Calder Grove, Wakefield.
 ROBSON, R., 2, Thornley Terrace, Tow Law, R.S.O., Co. Durham.
 ROBSON, WILLIAM, Jun., Tow Law, R.S.O., Co. Durham.
 ROEBUCK, WALTER, Talk-o'-th'-Hill Colliery, Stoke-upon-Trent.

SCOTT, E. CHARLTON, Rainton Colliery, Fence Houses.
 SEVERS, WILLIAM, Beamish View, *via* Chester-le-Street.
 SHAW, CHARLES, Jun., Woodland View, Froghall, Stoke-upon-Trent.
 SHAW, JOHN, Belmont Villa, Chapeltown, near Sheffield.
 SHELDON, JOHN, Eastwood, Nottingham.
 SHENTON, JOHN, Silverdale, Staffordshire.
 SHORE, THOMAS, Ireland Colliery, Staveley, Chesterfield.
 SHUFFLEBOTHAM, DANIEL, Biddulph Valley Collieries, Stoke-upon-Trent.
 SHUTTLEWORTH, ARTHUR, Park Terrace, Worsbrough Park, near Barnsley.
 SIMPSON, NELSON ASHBRIDGE, Bradley Hall, Wylam-upon-Tyne.
 SOAR, CHARLES, Granville Colliery, Swadlincote, Burton-upon-Trent.
 SOUTHERN, J., Heworth Colliery, Newcastle-upon-Tyne.
 SOUTHERN, J. C., 9, Success Cottages, Bunkers Hill, Fence Houses.
 SOWERBY, CHARLES, Town End, Emley, Wakefield.
 SPRY, JOHN, Murton Colliery, Co. Durham.
 STEPHENSON, S., The New Dale Colliery Company, Limited, Rawmarsh, Rotherham.
 STEPHENSON, W., Hewitson Terrace, Felling-upon-Tyne.
 STOKOE, JAMES, 10, The Avenue, Murton Colliery, Co. Durham.
 SWALLOW, F. C., Ynscedwyn Colliery, Ystradgynlais, Swansea.

TAIT, JAMES, South Kirkby Colliery, near Wakefield.
 TARBUCK, HAROLD, 102, Kennington Avenue, Ashley Down, Bristol.
 THOMPSON, JOSEPH, 12, The Avenue, Murton Colliery, Sunderland.
 THOMPSON, J. W., Greenfield House, Crook, R.S.O., Co. Durham.
 THOMSON, WILLIAM S., Cadzow Colliery, Hamilton, N.B.

TRUMAN, JAMES, Cadley Hill Colliery, Burton-upon-Trent.
TURNER, GEORGE, Cornsby Colliery, Co. Durham.

URWIN, JOHN, Inkerman House, Usworth Colliery, Co. Durham.

VARLEY, JOHN, Walker Street, Eastwood, Notts.

WAIN, JOSEPH, The Chatterley Whitfield Collieries, Bucknall, Stoke-upon-Trent.
WAINWRIGHT, GEORGE, Rock House, Talke, Stoke-upon-Trent.
WALLETT, THOMAS, 94, Charlton's Terrace, Guisbrough, R.S.O., Yorkshire.
WALTON, JAMES, Darfield Main, Wombwell, Barnsley.
WALTON, M., Dearham Colliery, Carlisle.
WARDLE, RICHARD, Dunsil House, Fackley, Mansfield.
WATKIN, R., Cortonwood Collieries, West Melton, near Rotherham.
WATSON, THOMAS, East Hedley Hope, Tow Law, R.S.O.
WHARTON, GEORGE, Egstowe Terrace, Clay Cross, Chesterfield.
WHITEHURST, HENRY, Grange Colliery, Burslem, Staffordshire.
WILBRAHAM, AARON, Mexboro' House, Selston, Alfreton.
WILLIAMSON, S. E., Netherseal Colliery, Burton-upon-Trent.
WILSON, JACOB, Hucknall Huthwaite, Mansfield.
WILSON, R. G., Pelton Colliery, Chester-le-Street.

ZELLER, C. VAN, Villar Oporto, Portugal.

Students.

ADAMS, CHARLES, Whitfield Collieries, Norton-in-the-Moors, Stoke-upon-Trent.
ALLOTT, J. R. L., Kinsley House, Kinsley, Hemsworth, near Wakefield.
ALLPORT, E. A., 89, Dodworth Road, Barnsley, Yorkshire.
ARCHER, M. W., High Priestfield, Lintz Green, Co. Durham.

BARNATTYNE, CLAUDE, 21, Circus, Bath.
BELL, WILLIAM, Elswick Collieries, Newcastle-upon-Tyne.
BONSER, H. E., Hucknall Huthwaite, near Mansfield.
BOOTH, FRED. L., Ashington Colliery, Morpeth.
BOOTH, J. T., Longstile, Talke, Stoke-upon-Trent.
BRODHURST, B. L., Glapwell Colliery, Chesterfield.
BROMLEY, OLIVER J., Leycett, near Newcastle, Staffordshire.
BURNE, CECIL A., Langley Park Colliery, Durham.
BURT, ANDREW, Halbeath Colliery, Dunfermline, N.B.
BURY, CHARLES, The Dale, Conisborough, Rotherham.

CADMAN, JOHN, Durham College of Science, Newcastle-upon-Tyne.
CARPENTER, S. W., Trevatham, Albemarle Road, Beckenham, Kent.
CARTER, W. H., Glapwell Colliery, Chesterfield.
CHAMBERS, F. E., Kenwadhi Colliery, Dhunbaid P.O., via Barakur, E.I.R.,
Calcutta, India.
CHECKLAND, B. H., Compton Street, Derby.

CHRISTIE, THOMAS TRAIN, Newcome, Uddingston, N.B.
 COWAN, HENRY D., Elswick Collieries, Newcastle-upon-Tyne.
 CRIGHTON, G. E., c/o Mrs. Cunliffe, Warpleston, Guildford, Surrey.

DAVY, G. C. H., Manvers Main Colliery, Wath, near Rotherham.
 DAVY, G. H., 14, Steade Road, Sharrow, Sheffield.
 DENTON, JOHN, Netherseal Colliery, Burton-upon-Trent.
 DIXON, GEORGE, Trimdon Grange, Co. Durham.
 DREW, WALTER N., Tankersley Cottage, Wharnccliffe Silkstone, Barnsley.

EAMES, WILLIAM, Cliff Cottage, Tuttle Hill, Nuneaton.

FALCON, MICHAEL, 23, Cemetery Road, Treorchy, South Wales.
 FAWCUS, C. W. M., Menehay, near Falmouth.
 FOWLER, G. C., Cliff Houses, Cinder Hill, Nottingham.

GOODALL, E. M., Eckington Collieries, Sheffield.
 GOULD, CHALKLEY VIVIAN, Rosedale, Alsager, Stoke-upon-Trent.
 GRAY, J. W., Dorrington, Athlone, Ireland.
 GREENE, CHARLES C., South Durham Colliery, Eldon, Bishop Auckland.
 GRIFFITH, N. MAURICE, The Broughton and Plas Power Coal Company, Limited,
 near Wrexham.

HALL, R. O., Treeton, Rotherham.
 HALPIN, W. L., Bridgewater Offices, Walkden, near Bolton, Lancashire.
 HANCOCK, J. G., Bolsover Colliery, Chesterfield.
 HARDY, W. H., Greenhill, Eastwood, Notts.
 HEATHCOTE, C. H., Newstead Colliery, Nottingham.
 HENDERSON, WILLIAM H., Anglo-American Club, Freiberg, Saxony, Germany.
 HETHERINGTON, J. RIDLEY, c/o Mr. Burnley, Sisters Villas, Garforth Colliery,
 near Leeds.
 HIRST, G. F., Rotherham Main Colliery, near Rotherham.
 HOLLAND, LAWRENCE, The Coppice, Brownhills, Walsall.
 HOMER, J. EDWARD, Hightown, Congleton.
 HOUFTON, P. B., Cresswell Colliery, Mansfield.

IMESON, J. A.

JACKSON, H. E., 3, Queen's Road, Erith, Kent.
 JOHNSON, G. W.
 JONES, WILLIAM, Trimdon Grange Colliery, Trimdon Grange, R.S.O.

KING, FRED., South Farm, Cramlington, Northumberland.
 KNIGHT, FRANCIS W., Newcastle, Staffordshire.

LANGFORD, D. B., Wellington Road, Camborne, Cornwall.
 LATIMER, HUGH, South Durham Colliery, Eldon, Bishop Auckland.
 LAWTON, T. A., Waen and Nerquis Collieries, Chester Street, Mold, North
 Wales.

LEACH, G. C., Birchill Lodge, Hasland, Chesterfield.
LONGBOTHAM, CHARLES E., Barrow Collieries, Barnsley.
LONGDEN, G. A., Stanton-by-Dale, Nottingham.
LYNAM, R. B., Shelton Steel and Iron Company, Stoke-upon-Trent.
LYON, J. W., The Firs, Annesley, Nottingham.

MCGOWAN, ERNEST, 29, Westmoreland Road, Newcastle-upon-Tyne.
MACKINTOSH, KENNETH P., c/o Mr. Neish, St. Fillans, Perthshire.
MAKEPEACE, R. R., Central Colliery, Bucknall, Stoke-upon-Trent.
MARSHALL, C. C., Gayton Hall, Ross, Herefordshire.
MARTIN, DANIEL, Jun., Clydeside Cottages, Broomhouse, N.B.
MAW, J. W., Oaks Collieries, Barnsley.
MIRRIELES, H. L.
MIDDLETON, H. W., Durham College of Science, Newcastle-upon-Tyne.
MINNS, THOMAS TATE, Jun., Greenhill House, Murton Colliery, Sunderland.
MITCHESON, HARRY, Dresden, Longton, Staffordshire.
MITTON, H. E., Cotton Mill, Langwith, near Mansfield.
MORRIS, H. S., 10, South Terrace, Camborne, Cornwall.
MORTON, PERCY CHARLES, Waleswood Colliery, near Rotherham.
MOXON, J. B., The Beeches, Rugeley.
MUSGROVE, WILLIAM, Throckley Colliery Office, Throckley Colliery, near Newcastle-upon-Tyne.

NEAL, JOHN, Jun., Middleton, Leeds.
NICHOLAS, C. COWELL, 14, Avenue Road, Doncaster.
NICHOLSON, THOMAS PERCY, Sharon, Rotherham.
NISBET, NORMAN, 17, Latimer Street, Tynemouth.
NIXON, JOHN, Stafford Coal and Iron Company, Stoke-upon-Trent.
NOBLE, ALGERNON, Broomhill Colliery, Acklington, Northumberland.

PARRINGTON, T. E., Hill House, Monkwearmouth.
PAYNE, H. G., Stretton Lodge, St. Faith's Road, London.
PEAKE, F. G., Walsall Wood Colliery, Walsall.
PEEL, J. W., Coundon, Bishop Auckland.
PILKINGTON, L. G., Bolsover, near Chesterfield.
PRESTON, W. J., Bolsover, near Chesterfield.

RAINE, FRED. J., Cornsby Colliery, Co. Durham.
RATCLIFFE, PERCY, Tibahelf, Alfreton.
RKES, J. H., Berry Hill Collieries, Stoke-upon-Trent.
RHODES, H., Rotherham Main Colliery, Rotherham.
RICHARDSON, M. D. R., Bestwood Colliery, Notts.
RICHARDSON, NICHOLAS, Heworth Colliery, Felling, R.S.O., Co. Durham.
RIGBY, JOHN, Stanton Hill, Mansfield.
ROBERTS, F. F., c/o Mr. Mercer, 1, Park Crescent, Wigan, Lancashire.
ROBINSON, F. K., Ellistown Collieries, near Leicester.
ROBSON, H. D., c/o L. F. R. and C. Goldfields, Limited, Arrowhead, British Columbia, *via* Queenstown and New York.
ROUTLEDGE, ROBERT, Murton Colliery, near Sunderland.

- SAMPLE, J. BEETRAM, Beamish Air Pit, Stanley, R.S.O., Newcastle-upon-Tyne.
SAUNDERS, W. A.
SAVAGE, A. T. C., Cossall Collieries, Nottingham.
SAXTON, ISAAC, Hasland, Chesterfield.
SCOTT, WILLIAM R., 56, Braid Road, Edinburgh.
SEVERS, JONATHAN, Stanley, R.S.O., Newcastle-upon-Tyne.
SHAW, EDGAR H., Adderley Green Collieries, Stoke-upon-Trent.
*SHERWEN, J. H., Whitehaven Collieries, Whitehaven.
SIMPSON, R. R., 11, Haldane Terrace, Jesmond, Newcastle-upon-Tyne.
SIMPSON, THOMAS V., Heworth Colliery, Felling, R.S.O., Co. Durham.
SMITH, ERNEST E., Chatterley Whitfield Collieries, Tunstall, Staffordshire.
SOUTHALL, A. B., Jun., Monckton, Barnsley.
SOUTHERN, STEPHEN, Heworth Colliery, Felling, R.S.O., Co. Durham.
STEELE, W. R., Barrow Collieries, Barnsley.
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TRANSACTIONS
OF
THE FEDERATED INSTITUTION
OF
MINING ENGINEERS.

THE FEDERATED INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,
HELD IN THE LORD MAYOR'S PARLOUR, TOWN HALL, MANCHESTER,
FEBRUARY 17TH, 1897.

MR. LINDSAY WOOD, PRESIDENT, IN THE CHAIR.

Ald. HOPKINSON said that he was deputed by the Lord Mayor (Ald. J. Foulkes Roberts) to express his great regret that he was unable to bid the members welcome to Manchester. He had hoped to be at liberty for the purpose of welcoming the Institution, but he was engaged in such a way that he could not do so.

The PRESIDENT said that the members were sorry that the Lord Mayor was not able to attend the meeting. He had pleasure in moving a vote of thanks to the Lord Mayor for allowing the members to have the use of his room for their meeting.

The vote was carried by acclamation.

DISCUSSION UPON MR. H. BRAMWELL'S PAPER ON "THE
COMPOUND WINDING-ENGINE AT THE GREAT WEST-
ERN COLLIERY COMPANY'S TYMAWR PIT: WITH
NOTES ON ITS COMPARATIVE STEAM ECONOMY."*

Mr. J. GREGORY said that it would be interesting to know what system of guides was adopted at the pit in question. It appeared to him that in the case of a deep pit fitted with wire-rope guides, the

* *Trans. Fed. Inst.*, vol. xii., page 282.

system of compounding the engines described by Mr. Bramwell would be useless, on account of the swaying set up by the irregular motion of the engine, and it would be seen from Mr. Bramwell's paper that some little trouble had been experienced on that account. A preferable arrangement would be to place the high- and low-pressure cylinders, tandem-fashion, on each side of the winding-drum in a manner similar to that adopted at the Sneyd colliery, Burslem. The compound winding-engine would then be as well balanced as an ordinary high-pressure engine, and the complication introduced by using an additional lever to introduce high-pressure steam to the low-pressure cylinder would be avoided.

Mr. W. GALLOWAY said that perhaps Mr. Gregory had not read his paper, published before Mr. Bramwell's, in which he described a tandem compound winding-engine.*

Mr. GREGORY said that he had formed the idea that, having a high-pressure cylinder on one side and a low-pressure on the other side, considerable swaying of the ropes would be produced.

Mr. W. GALLOWAY said that he had visited the Great Western colliery a few days ago, and, although it was 1,440 feet deep, there was no unusual vibration of the winding-ropes.

Mr. B. WOODWORTH said that, with two cylindered compound winding-engines, tolerable steady running was obtained when the effective work of each cylinder was almost equal. As a good speed was attained by the Tymawr pit winding-engine before the expansion-gear came into action, the weights of matter in motion ensured steadiness afterwards, but he preferred the double tandem arrangement with the cut-off brought into action at the earliest possible moment. With a suitable adjustment of the main valves and gear, the results obtained without cut-off at the Hetty pit winding-engine would have been equally efficient, as the cut-off was as low as 50 per cent. and too late in its action. He had seen a large winding-engine, where the expansion-gear came into action after 75 per cent. of the work had been done.

Mr. W. GALLOWAY said that when he visited Tymawr recently, he was told they intended to put a cut-off on the low-pressure cylinder and hoped to attain the results which Mr. Woodworth anticipated would ensue.

Mr. H. BRAMWELL (Great Western collieries), replying to the discussion, wrote that the Tymawr shaft was fitted with rope-guides, and

* *Trans. Fed. Inst.*, vol. xi., page 207.

although small and with little clearance, no particular difficulty was experienced in the running of the cages, the swaying of the ropes being less than in many other shafts within his (Mr. Bramwell's) knowledge. The irregular motion of the engine anticipated by Mr. Gregory was not experienced in practice, although undoubtedly a better balance of power was obtained by Mr. Galloway in his compound winding-engine at Llanbradach colliery, and by the Sneyd colliery winding-engine mentioned by Mr. Gregory.

As stated in his (Mr. Bramwell's) paper, the additional lever and valve for admitting high-pressure steam to the low-pressure cylinder in cases of emergency, was not used in ordinary work.

Mr. Woodworth, in his remarks on the Hetty pit winding-engine, appeared to have overlooked his (Mr. Bramwell's) statement that a non-expansive high-pressure engine could no doubt be designed to give considerably more economical results than the Hetty pit engine did when the existing expansion-gear was disconnected. At the same time, he (Mr. Bramwell) differed from Mr. Woodworth in his opinion that the present Hetty pit winding-engine could be altered so as to give as good results working non-expansively as it now did with the cut-off in use, even though the latter were adjusted to attain a maximum of only 50 per cent. of the stroke. In a winding-engine, where the cut-off was varied by a governor, the point of maximum cut-off was very largely under the control of those who designed and worked the particular winding plant, and he (Mr. Bramwell) hardly thought that Mr. Woodworth intended his remarks to now raise the question of the advisability of working large winding-engines expansively or not.

In conclusion, he (Mr. Bramwell) endorsed Mr. Galloway's opinion, that interesting results in the way of steam-consumption could probably be obtained from winding-engines that were usually looked upon as models of excellence.

Mr. HENRY HALL (H.M. Inspector of Mines, Liverpool) read the following paper on "The Cost and Efficiency of Safety-explosives as Compared with Gunpowder":—

THE COST AND EFFICIENCY OF SAFETY-EXPLOSIVES AS COMPARED WITH GUNPOWDER.

BY H. HALL, H.M. INSPECTOR OF MINES.

In view of the Explosives in Coal Mines Order recently issued by the Secretary of State, which will shortly come into operation, the writer believes that any reliable information as to the cost and efficiency of what have been named in that order "permitted explosives," will be of interest and acceptable to the members.

The members are no doubt aware that the "permitted explosives" have been selected as being the most suitable and reliable in the light of present knowledge ; some may eventually have to be dispensed with, and others may take their place, but the writer does not propose to discuss here the expediency of the selection. He wishes simply to put the members in possession of the best information obtainable as to their practical efficiency and cost in mines where they have already been adopted.

The West Lancashire mines inspection-district has been the cradle and battlefield of what are termed safety-explosives. Roburite manufactured near Wigan has borne the brunt of the fight, and has survived strikes and opposition on all sides, until now it, or some of the younger "ites," have ousted and taken the place of gunpowder in all the larger collieries, and it is here alone that the practical effect of the change has been fully realized.

At the risk of trespassing on the good nature of the managers of the different works, statistics have been asked for and obtained which show an actual comparison between a period of one year during which gunpowder was the blasting agent and a similar period under the new *régime* of safety-explosives.

The outlay for explosives and the production of round coal under the two systems have been carefully taken from the colliery accounts, the last whole year in which gunpowder was used being selected for such examination in the one case, and the year 1896 for the safety-explosives. The same seam, or the same colliery as a whole, is in each instance compared for the two periods.

The extraction of these figures from the accounts has no doubt taken considerable time and trouble, and it has only been the fear of giving this trouble which has limited the enquiry to some twenty firms, but when it is seen that the statistics in each individual case prove almost identical facts, the writer submits that the conclusions can hardly be called in question. The enquiry embraces mines giving an annual output of 5,000,000 tons, and in several instances the experience with safety-explosives extends to eight or nine years.

A form (Appendix A) was issued to obtain the necessary particulars for comparison, and the returns are tabulated; the marginal notes explaining the reason of omissions and blanks which appear in Table I.

It is somewhat difficult to analyse and fix with certainty the precise results of the statistics contained in Table I., but averaging the figures of the cost per ton for explosives (column 9), we get an average cost per ton for gunpowder of 0·61d., and for safety-explosives of 0·92d., or 0·31d. more for safety-explosives than gunpowder, and we may argue from this, that whatever the cost of blasting with gunpowder has been in a particular seam, that cost will be increased by one-half by changing to safety-explosives.

Dealing with the percentages of round coal in the same manner (column 12) we get an average of 62·2 per cent. of round coal with gunpowder, and an average of 62·0 per cent. for safety-explosives.

Personally, the writer believes from his experience that the addition of 0·31d. to the explosive cost per ton as deduced from the figures is, as an average, almost absolutely correct. He believes the actual effect on the production of round coal by the change to be much more difficult to determine, in consequence of recent changes in the methods of screening and cleaning coal and the varying conditions of the mines at different periods. He was not prepared to find, as the figures seemed to show, that there was as good a percentage of round coal with safety-explosives as with gunpowder.

This enquiry has been confined to coal-getting, as no one will be likely to question the economy of the safety class of explosive for stone-work. In taking down rock there is an advantage of at least 25 per cent. over gunpowder. A case was pointed out to the writer a day or two ago, where in a rock-catch 2 feet thick by 7 feet wide, both classes of explosive had been tried, and the work progressed almost twice as fast with ammonite as with gunpowder. In metals, the one class is quite equal to the other.

TABLE I.

Number of Colliery.	Kind of Explosive.	Name of Coal-seam.	Thickness of Seam.	Quality: Hard or Soft.	Method of Working.	Coal raised in the Year.	Total Expenditure on Explosives, Fuse, Detonators, Cables, etc.	Cost of Explosives per lb. of Coal raised.	Price of Explosive per lb., Net.	What Year.	Percentage of Round Coal produced.
(a) No. 1.—North Wales	Gunpowder ..	Main ..	Ft. In. 6 0	Hard ..	Longwall and Pillar-and-Stall ..	Tons. 273,649	£ s. d. 313 15 6	d. 0.34	d. —	1888	78.09
	Electronite ..	Main ..	6 0	Do.	Do.	249,498	800 12 8	0.77	9	1898	78.41
	Gunpowder ..	Four-feet ..	5 0	Do.	Longwall ..	153,946	419 15 3	0.64	—	1888	78.09
	Electronite ..	Four-feet ..	5 0	Do.	Do.	187,222	713 11 2	8	9	1896	78.41
(b) No. 2.—Lancashire†	Gunpowder ..	Ince Four-feet ..	3 10	Hard ..	Pillar-and-Stall and Longwall ..	63,157	{ 81 13 3* 14 2 8†	{ 0.31 0.15 }	4	1894	65.00
	Ammonite ..	Ince Four-feet ..	3 10	Do.	Do.	53,117	143 3 10*	0.36	10½	1896	64.00
	Gunpowder ..	Orrell Four-feet ..	2 8	Do.	Longwall ..	59,173	{ 63 9 11* 121 3 4†	{ 0.26 0.49 }	4	1888	58.00
	Ammonite ..	Orrell Four-feet ..	2 8	Do.	Do.	99,182	{ 233 15 10* 254 4 11†	{ 0.61 0.61 }	10½	1893	60.00
(c) No. 3.—Lancashire ..	Gunpowder ..	Potato Delf and Main Delf ..	3 9	Soft ..	Pillar-and-Stall and Longwall ..	154,151	299 11 0	0.46	5½	1895	51.6
	Ammonite ..	Do.	3 9	Do.	Do.	139,100	318 10 0	0.54	12	1896	52.10
(d) No. 4. Lancashire	Gunpowder ..	Arley ..	4 0	Hard ..	Longwall ‖	48,500	126 8 10	0.62	4	1895	76.00
	Roburite ..	Arley ..	4 0	Do.	Do.	40,880	174 13 9	1.02	10½	1896	71.00
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)

(a) The manager observes: "When we commenced to use high explosives the bars were reduced from 1 inch to ½ inch, excepting one screen, which was ½ inch in 1888."

(b) The screen-bars for the Ince four-feet coal were the same in each year, and the method of working the same. The screen-bars for the Orrell four-feet coal were the same in each year. The manager remarks that in 1888 the coal was worked on the face, and in 1896 on the end.

(c) The screens in 1885 were ½ inch bars, and in 1896 shaker-screens with 1 ½-16 inch mesh.

(d) The screens were the same in both years.

* Colliers.

† Contractors, explosives used for stone-work.

‡ The percentage of round coal for the firm as a whole was 57.75 in 1888, and 61.50 in 1896.

‖ Coal is holed on the top of the seam.

TABLE I.—Continued.

Number of Colliery.	Kind of Explosive.	Name of Coal-seam.	Thickness of Seam.	Quality: Hard or Soft.	Method of Working.	Coal raised in the Year.	Total Expenditure on Explosives, Fuses, Detonators, Cables, etc.	Cost of Explosives per Ton of Coal raised.	Price of Explosive per lb., Net.	Whole Year.	Percentage of Round Coal produced.
(c) No. 5.—North Wales	Gunpowder ..	Five-yards ..	Fr. In. 10 0	Medium ..	Pillar-and-Stall ..	Tons. 26,206	66 18 9	0.13	d.	1891	60.16
		Five-feet ..	3 6	Do.	Longwall ..	30,226					
		Three-yards ..	6 0	Hard ..	Do.	5,264					
	Ardeer powder ..	Five-yards ..	10 0	Medium ..	Pillar-and-Stall ..	130,668	28 4 8	0.16	d.	1896	59.62
		Five-feet ..	3 6	Do.	Longwall ..	70,534	12 17 3				
		Three-yards ..	6 0	Hard ..	Do.	53,903	43 15 11				
(f) No. 6.—North Wales	Gunpowder ..	Durbog ..	5 9	Medium ..	Pillar-and-Stall ..	21,315	84 17 10	1.76	d.	1896	65.54
		Durbog ..	5 9	Do.	Do.	125,751	211 9 2				
		Durbog ..	7 0	Medium ..	Pillar-and-Stall ..	28,737	253 10 0				
(g) No. 7.—Lancashire ..	Gunpowder ..	Wigan Six-feet ..	7 0	Do.	Do.	30,099	134 3 0	0.53	d.	1896	66.53
		Wigan Six-feet ..	7 0	Do.	Do.	60,000	518 9 6				
		Wigan Six-feet ..	7 0	Do.	Do.	74,522	687 3 8				
(h) No. 8.—Lancashire ..	Gunpowder ..	Pemberton, Wigan, and Arley Seams ..	3 ft. to 7 ft. 6 in.	Hard and Soft ..	Pillar-and-Stall and Longwall ..	431,040	476 10 6	0.43	d.	1896	Not known.
		Do.	Do.	Do.	Do.	270,931	212 1 0				
		Do.	Do.	Do.	Do.	101,390	212 1 0				
(i) No. 9.—Lancashire ..	Gunpowder ..	Florida ..	3 ft. 6 in.	Hard ..	Longwall ..	77,717	213 8 4	0.67	d.	1896	66.44
		Do.	Do.	Do.	Do.	110,332	611 0 6				
		Do.	Do.	Do.	Do.	89,616	409 17 1				
(1)	Gunpowder ..	Five-feet and Four-feet ..	3 ft. 6 in. to 6 ft. 6 in.	Hard ..	Pillar-and-Stall ..	409 17 1	(6)	1.33	d.	1896	67.38
		Do.	Do.	Do.	Do.	89,616	(7)				
		Do.	Do.	Do.	Do.	409 17 1	(8)				

(c) The screen-bars were the same in each year. The manager remarks: "We have only the total cost of gunpowder and fuse for the colliery as a whole, including coal-getting and stone-work for 1891. The cost includes stone-work." (f) This comparison is made between two districts of the same coal-seam, in one of which gunpowder is used, and in the other a safety-explosive. The coal is riddled underground. All the work was straight work.

(g) Gelignite is not on the permitted list. The screen-bars were the same in each year. (h) The statistics are for the whole colliery, and the production of round coal is not known. The cost includes stone-work. (i) The screen-bars and method of working were the same in each year. The screen-bars were $\frac{3}{4}$ inch wider apart in 1896.

TABLE I.—Continued.

Number of Colliery.	Kind of Explosive.	Name of Coal-seam.	Thickness of Seam.	Quality: Hard or Soft.	Method of Working.	Coal raised in the Year.	Total expenditure on Explosives, Fuze, Detonators, Cables, etc.	Cost of Explosives per Ton of Coal raised.	Price of Explosives per lb., Nett.	What Year.	Percentage of Round Coal produced.
(j) No. 10.—Lancashire	Ballite and Electro-nite Gunpowder ..	—	2 ft. 6 in. to 5 ft. 6 in. Do.	Fairly Hard .. Do.	Pillar-and-Stall and Longwall Do.	Tons 774,347 520,571	£ 2,914 4 2 —	d. 0 90 —	10 and 94 —	1886 1886 1886 1886	57·05 54·00 60·00 Unscreened
(k) No. 11.—Lancashire	Gunpowder ..	Wigan Four-feet and Nine-feet ..	4 10	Hard ..	Pillar-and-Stall ..	140,000	285 14 1	0 45	—	1886	60·00
(l) No. 12.—Durham	Roburite ..	Bursy ..	5 7	Soft ..	Bord-and-Pillar ..	101,866	433 19 6	1 02	—	1886	Unscreened
(m) No. 13.—Lancashire	Gunpowder ..	Bickershaw Seven-feet Do.	6 9	Hard ..	Bord-and-Pillar ..	50,333	Not known.	Not known.	—	1883	65·00
	Ammonite ..	Pemberton Four-feet Do.	6 9	Do.	Do.	119,578	470 7 7	0 94	10	1886	58·00
	Gunpowder ..	—	4 0	Hard ..	Bord-and-Pillar ..	104,368	Not known.	Not known.	—	1882	60·20
	Roburite ..	—	4 0	Do.	Do.	39,268	117 6 7	0 71	10	1886	63·00
(n) No. 14.—Lancashire	Gunpowder ..	—	3 ft. to 8 ft.	Various ..	Pillar-and-Stall and Longwall Do.	457,215	Not known.	Not known.	—	1887	61·70
	Roburite and Ammonite Gunpowder ..	—	3 ft. to 8 ft.	Do.	Do.	725,217	2,587 17 4	0 85	94 and 10	1896	61·53
(o) No. 15.—Lancashire	Carbonite ..	—	3 ft. to 6 ft. 6 in. Do.	Various, hard generally Do.	Pillar-and-Stall and Longwall Do.	219,031	771 2 8	0 84	3	1892	—
	Gunpowder ..	—	3 ft. to 7 ft.	Hard generally	Pillar-and-Stall and Longwall Do.	190,434	1,331 0 0	1 70	9	1896	—
(p) No. 16.—Lancashire	Carbonite ..	—	Do.	Do.	Do.	1,250,000	Not known.	—	—	1886	51·00
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)

(j) Cost of stone-work is included. All coal-shots are fired after the colliers have left the mine.

(k) Safety-explosives have not been used in these seams, and the cost does not include stone-work.

(l) Particulars are not available for a year in which blasting-powder was used.

(m) The percentage of round coal for the colliery in 1882, when gunpowder was used throughout, was 60·40 for a production of 600,000 tons, and in 1886, with safety-explosives throughout, the percentage was 60·10 for a production of 760,000 tons. The year 1883 was more favourable for the production of round coal than 1886. The coal in the Bickershaw seven-feet coal-seam was chiefly wrought from crushed pillars in 1886. The manager states that he finds from experiments that 4 per cent. more slack was made with 1½ inches mesh shaker-screens, than with ½ inch bar-screens.

(n) Miners bought gunpowder at 5d. per lb. from outside shops, and the amount cannot be given. The screens were the same in both years.

(o) In 1882, screen-bars ½ inch apart were used, and in 1886 shaker-screens with mesh of 1½ inches.

The fumes from safety-explosives have not proved to be injurious, although when first introduced there was some difficulty with the workmen on that ground, but this opposition had now entirely died away. The fumes are much less dense than those of gunpowder, and are more rapidly carried away by the ventilating air-current.

The general conclusion to be drawn from the statistics which the writer has had the privilege of submitting to the members must be, that the practical effect of the "Explosives in Coal Mines Order" will by no means prove so formidable from a commercial point of view as has been represented in some quarters; and he estimated that a sum substantially less than one penny per ton will defray the whole cost.

Mine-owners have not been severely dealt with in the matter of legislation during the past twenty years. It would be difficult to point to any legal requirement which a prudent miner would not of his own option have adopted in the absence of legislation which has added materially to cost.

Under the head of efficiency of the two classes of explosives, it is legitimate to consider the still more important question of safety.

With this view, the writer proposes to compare the West Lancashire mines inspection-district—one notoriously fiery, and where safety-explosives, safety-lamps, and official shot-firers have become the rule—with Northumberland, a district specially favoured by nature, where as yet in the steam-coal collieries none of these safeguards have been introduced, and where candles, gunpowder, and collier shot-firers still prevail.

There appears to be a serious misconception with regard to Northumberland. It has been asserted that fire-damp explosions are almost unknown, and that accidents with explosives are so rare, and so trifling, that any change of method is uncalled for, and could only make matters worse in that district.

Table II. shows that in the Northumberland district there was an average of 2·4 deaths per annum by accidents with explosives, while in the West Lancashire district it was only 0·6 per annum, and dividing these figures into the average number of persons employed underground, we have 1 death in the former district in every 23,130 persons, as against 1 death in every 76,700 in the latter. The figures, in the case of persons injured, are Northumberland 1 in 1,735, and Lancashire 1 in 4,602. In other words, there have been more than three times as many persons killed in the Northumberland district through accidents with explosives in proportion to the number of persons underground as there have been in

West Lancashire, and nearly three times as many injured during the last five years.

TABLE II.—SHOWING THE NUMBER OF PERSONS KILLED AND INJURED BY EXPLOSIVES (GUNPOWDER, ETC.) IN THE NORTHUMBERLAND MINES INSPECTION-DISTRICT, AS COMPARED WITH THE WEST LANCASHIRE AND NORTH WALES INSPECTION-DISTRICT, DURING THE LAST FIVE YEARS.

Years.	Northumberland Mines Inspection-District.			West Lancashire and North Wales Mines Inspection-District.		
	Killed.	Injured.	Persons Employed Underground.	Killed.	Injured.	Persons Employed Underground.
1892	2	27	54,397	0	13	46,044
1893	0	38	54,325	0	12	46,444
1894	1	35	56,726	1	7	47,108
1895	7	29	56,076	0	6	46,587
1896	2	31	56,076*	2	12	43,928
Totals and averages	12	160	55,520	3	50 $\frac{1}{2}$	46,022

* 1895 figures taken, 1896 not being available yet. The numbers of accidents are those for 1896.

Table III. shows that in the Northumberland district there was an average of 2 deaths per annum by fire-damp explosions, whilst in West Lancashire it was only 0·4 per annum, and dividing these figures into the average number of persons employed underground we get 1 death in the former district for every 27,760 persons, as against 1 death for every 115,050 in the latter. The figures, in the case of persons injured, are Northumberland 1 in 5,552, and Lancashire 1 in 11,505. In other words, there have been four times as many persons killed by explosions of fire-damp in the Northumberland district as in Lancashire, and twice as many injured in the last five years.

TABLE III.—SHOWING THE NUMBER OF PERSONS KILLED AND INJURED BY FIRE-DAMP EXPLOSIONS IN THE NORTHUMBERLAND MINES INSPECTION-DISTRICT, AS COMPARED WITH THE WEST LANCASHIRE AND NORTH WALES MINES INSPECTION-DISTRICT, DURING THE LAST FIVE YEARS :—

Years.	Northumberland Mines Inspection-District.			West Lancashire and North Wales Mines Inspection-District.		
	Killed.	Injured.	Persons Employed Underground.	Killed.	Injured.	Persons Employed Underground.
1892	2	13	54,397	0	1	46,044
1893	2	12	54,325	1	4	46,444
1894	1	12	56,726	0	3	47,108
1895	1	7	56,076	1	9	46,587
1896	4	8	56,076*	0	2	43,928
Totals and averages	10	52	55,520	2	19	46,022

* 1895 figures repeated, 1896 not yet being available. The accidents are those for 1896.

The figures recorded in Tables II. and III. are somewhat startling, but the lesson which they convey is clear and decisive. It would appear that by obstinate adherence to antique methods of mining, such as candles, gunpowder, and collier shot-lighters, a district, naturally safe, has become less free from accident than one naturally dangerous.

The writer looks in vain for any compensating circumstances to warrant the continuance of these primitive methods of mining. He is aware that it is persistently asserted that candles afford a better protection against "falls of roof," but this opinion has been proved again and again to be a fallacy.

If we compare the "falls of roof," in the two northern mining districts, viz., Durham and Northumberland, in the former of which safety-lamps are generally used, and in the latter candles largely prevail, and in both of which that excellent system of "deputy timbering" is practised we find apparently another proof that candles give no greater security against falls of roof than safety-lamps.

TABLE IV.—SHOWING THE NUMBER OF LIVES LOST THROUGH "FALLS OF ROOF AND SIDE" IN THE NORTHUMBERLAND MINES INSPECTION-DISTRICT AS COMPARED WITH THOSE LOST FROM THE SAME CAUSE IN THE DURHAM MINES INSPECTION-DISTRICT (EXCLUSIVE OF THE CLEVELAND IRONSTONE MINES).

Years.	Northumberland Mines Inspection-District.		Durham Mines Inspection-District.	
	Deaths.	Persons Employed Underground.	Deaths.	Persons Employed Underground.
1891	32	53,140	37	52,979
1892	37	54,397	26	52,422
1893	47	54,325	34	53,510
1894	37	56,728	34	55,572
1895	26	56,076	34	55,568
Totals and averages	179	54,932	165	54,010

Table IV. shows that in the Northumberland district, for the five years, we have an average number of 36 persons killed per annum by falls of roof and side, whilst in the Durham district the average number is only 33, and dividing these into the average number of persons employed underground, in each of the districts, we find that in Northumberland one person was killed in every 1,526, as against one in every 1,636 in Durham.

At the time of writing, the figures for 1896 are not available, but an advance proof of these figures shows that in Northumberland 36 lives were lost by falls of roof and side, and 32 in Durham.

It is obvious from Table IV. that the different methods of lighting in the two districts have no bearing upon the frequency or otherwise of falls of roof. It is possible that the steam-coal colliery, being presumably shallower and less liable to crush, can show a cleaner bill of health in this respect than the deeper collieries, but this is just what any miner would expect, quite apart from the fact of candles being used.

When we turn to the lists of explosions of gas and accidents with explosives given in H.M. Inspector's Annual Report for the Northumberland district, which form Appendices B and C to this paper, it will be seen at a glance that apparently the steam-coal collieries are very serious defaulters. In a list of 37 accidents, all the fire-damp explosions (6) were caused by candles, and out of 31 accidents with explosives, 29 were due to gunpowder, and mostly in conjunction with candles.

The practical coal-getter's experience with safety-explosives has convinced him that, at any rate for his cutting-shot, they are superior to gunpowder. The writer has several times been assured by individual colliers that it is better, even where they have the option of using gunpowder, to pay the higher price for a safety-explosive to be used in the cutting-shot; and by careful enquiries in the mines, this view has been verified, and is now generally held among the workmen.

The writer has endeavoured to remove misconceptions by arraying the facts of experience so far as they are available, believing that unsupported haphazard statements are worse than mischievous.

He thinks there is good ground for the hope that the general adoption of the "Explosives in Coal Mines Order" will minimize the risk of explosions of fire-damp or coal-dust which we now have to face from year to year.

APPENDIX A.

A.—Fill in the particulars below for the last whole year in which gunpowder was used in any seam for coal-getting (not stone-work).

Name of Seam.	Thickness of Seam.	Quality: Hard or Soft.	Method of Working.	Tons of Coal Raised in the Year.	Total Expenditure on Gunpowder and Screen-bars for the Year (Coal-getting).	Cost of Explosive per Ton of Coal Raised.	Percentage of Round Coal.*	What Year.			Remarks.

* NOTE.—If you have not actual figures from which to deduce the percentage of round coal, leave the column blank.

B.—Fill in the particulars below for the year 1896 for the same seam as above, when using safety-explosives instead of gunpowder for coal-getting (not stone-work).

Name of Seam.	Thickness of Seam.	Quality: Hard or Soft.	Method of Working.	Tons of Coal Raised in the Year.	Total Expenditure on Explosives, Detonators, Cables, etc.	Cost of Explosive per Ton of Coal Raised.	Percentage of Round Coal.*	What Year.	What Explosive.	Price per lb.	Remarks.

Were the screen-bars the same distance apart in each of the above years?

Was the method of working the seam similar in each of the above years?

NOTE.—If any of the men were buying their explosives from shops outside the collieries, cast these men and their coal out of the calculation. Do not charge shot-firers' wages.

APPENDIX B.—LIST OF EXPLOSIONS OF FIRE-DAMP IN THE NEWCASTLE MINES INSPECTION-DISTRICT IN THE YEAR 1895.

Date.	No.	Name of Colliery.	Name of Seam.	No. Killed.	No. Injured.	Barometer reduced to Sea-level.	Cause.
1895. April 18th	1	Throckley ...	Main Coal	—	2	Inches. 29.45 Slightly falling.	A shot had been fired in a top stone, but without bringing it down, and as one of the men was examining it with his candle, a little gas which had accumulated in the cracks was ignited, slightly burning the men, one of whom was off work for 5 days and the other for 3 days.
" 22nd	2	Heddon ...	Brockwell	1	—	29.45 Falling.	The deceased and another man were sent to repair a roadway and they had to pass under a brattice-cloth which had been put up to ventilate a hole in the roof. The deceased, for some reason, put up his candle and ignited some gas which had collected there.
June 24th	3	Cowpen (Mill)	Low Main	—	1	30.30 Rising.	The hewer had gone back from the face to eat his food, and on returning, a little gas which had collected in his absence, fired at his candle. Off work 21 days.
July 12th	4	Broomhill ...	Top Coal ...	—	1	29.50 Rising.	A gutter was travelling out-bye along an intake air road, when an explosion suddenly occurred. An inspection showed that there were some old workings in the vicinity from which the gas had evidently come, and lighted at his candle. There were signs of considerable force having been developed, but fortunately the seam is wet, otherwise the consequences would have been more disastrous. The injured man was off work for 110 days.
" 21st	5	East Holywell	Low Main...	—	1	29.30 Falling.	A rollerway-man went beyond a danger board into a damped place, and ignited some gas with his open light. Safety-lamps are used in the district, the main roads excepted. The caution-board has now been moved nearer to the pit-bottom. He was off work for 40 days.
Dec. 30th	6	Ravensworth (Shop)	Peaumont...	—	2	29.50 Rising.	The manager and overman were examining a stopping which had been erected at the top of an old and damped "stale" pit in the Peaumont seam, and from which gas occasionally issued. Nothing was detected when a safety-lamp was used, but when a naked light was incautiously taken to the place, an explosion occurred, resulting in the destruction of the stopping and slight injuries to the above-named officials, neither of whom were totally incapacitated from following their daily avocations.

APPENDIX C.—LIST OF EXPLOSIONS OF GUNPOWDER, ETC., IN THE NEWCASTLE MINES INSPECTION-DISTRICT, 1895.

Date.	No.	Name of Colliery.	Name of Seam.	No. Killed.	No. Injured.	Cause.
Jan. 5th	1	Cambois ...	Low Main	—	1	A road was being driven through the goaf, and it was found necessary to fire a shot. This was done in the presence of the chargeman, who neglected to warn the man working in the road approaching from the opposite direction, in sufficient time, and who, in the explosion of the shot, which blew through, was injured by the flame and flying debris. The explosive used was gunpowder. Off work 14 days.
Feb. 16th	2	Ashington	Yard	—	1	The shot went off before the man had time to get away. He was using a patent squib, and had evidently nipped off part of the touch, contrary to the directions printed on the packet. Gunpowder. Off work 7 days.
" 26th	3	Hartford ...	Yard	1	1	Two stonemen were charging a shot-hole with gelignite and when in the act of putting in a third cartridge, using a wooden stonmer, part of the charge exploded. An after-examination of the explosive remaining in the stone showed that it was frozen; hence the explosion. Injured man off work 56 days.
March 6th	4	Shire Moor	Yard	—	1	The man was carrying a cartridge of compressed gunpowder, which he was about to use, when by some means it came into contact with his candle, which must have been foolishly held in the same hand. Off work 91 days.
" 16th	5	Seaton Delaval ...	Stone	—	1	A cross-heading was about to hole through into another roadway, and sufficient care not having been taken to warn the man in the latter place when a shot was about to be fired, he was, as might have been expected, severely injured by the explosion, which shattered the narrow barrier of coal between the two places. Gunpowder. Off work 158 days.
" 28th	6	Pegswood...	Low Main	—	1	He was carrying his shot-box under his arm, when the lid came off, and the contents of the cartridges—falling on his candle, exploded, burning him slightly. Gunpowder. Off work 27 days.
" 29th	7	Seaton Delaval ...	Yard	—	1	The man went into an adjoining working-place to borrow a cartridge, when a shot, which had been lighted up, went off, resulting in severe injuries to his chest and ribs. The man who fired the shot stated that he had shouted to the men in the adjoining places, but it is evident that there must have been a considerable distance between the two places, and that the cartridges were on the part of one or other of the men. Gunpowder. Off work 122 days.
April 8th	8	Burradon ...	Yard	—	2	A stoneman and a shifter were struck by the flying stones from a gunpowder shot, owing to their not having retired to a safe distance after lighting the fuse. Off work 161 and 91 days respectively.
" 8th	9	Ashington	Yard	—	1	The candle fell on to the shot when the man was on the point of putting it into the hole, resulting in slight burns. Gunpowder. Off work 28 days.
" 16th	10	Felling ...	Bensham ...	1	—	It is not known how this accident occurred, as no one was present but the deceased, a shot-firer. He was using a squib, and it is possible that he did not allow himself sufficient time to get to a place of safety. Gunpowder.
May 7th	11	Ashington	Yard	1	—	A stoneman had lighted up a gunpowder shot, and thinking that it had misfired, returned to the place too soon, when it exploded upon him.

APPENDIX C.—Continued.

Date.	No.	Name of Colliery.	Name of Seam.	No. Killed.	No. Injured.	Cause.
May 23rd	12	Shire Moor	Bensham ...	1	—	▲ deputy had, unknown to the hewer in the adjoining working place, gone into a bord to "jowl" through to the latter, to ascertain the thickness of coal between the two places, and just as he was doing so, a shot, lighted up by the hewer, went off, blowing through into the bord, and killing the deputy on the spot. A breach of the rules had been committed by the hewer in not examining the adjoining place before lighting the shot, and he was subsequently prosecuted, and fined a small amount.
" 30th	13	Dudley ...	Low Main	—	2	The deputy fired a shot which failed to do its work. The hole was then re-charged with a larger amount of powder, and on the shot exploding the stemming was blown out, the deputy and the hewer being burnt by the following flame. Gunpowder. Off work 18 days and 178 days respectively.
June 14th	14	Dudley ...	Yard ...	—	1	▲ hewer was slightly burnt by the explosion of a bobbin of compressed gunpowder, on which he had carelessly dropped his candle. Off work 13 days.
July 18th	15	East Holywell ..	Main ...	—	1	The injured man was charging a stone-hole with bobbin cartridges, when the latter exploded; the hole was apparently too small, and he was recklessly standing in the line of fire, the consequence being that he was severely and permanently disabled through loss of eyesight.
" 25th	16	Ravensworth (Betty)	Low Main	—	1	▲ hewer fired a shot, which blew through into an adjoining place, burning the man who was working there, and who, although warned, had not retired to a safe distance. Gunpowder. Off work 53 days.
" 30th	17	Hartford...	Yard ...	—	1	He was lighting a fresh candle from a nearly burnt-out one, and at the same time had half a bobbin of compressed powder in his hand, which, it is not surprising to learn, was ignited. Gunpowder. Off work 33 days.
" 30th	18	Maud ...	Low Main	—	1	The shot went off immediately a light was applied to the squib, which had evidently been slipped short by the injured man. Gunpowder. Off work 33 days.
" 30th	19	Roachburn	Little Limestone...	—	1	He was putting a fuse into a detonator, and the hole being a wet one, very foolishly attempted to grease the joint at his candle, when the detonator exploded, resulting in the ignition of 24 others which were lying in an open box within 6 inches of his candle. Off work 116 days.
Aug. 1st	20	Whitburn	Bensham ...	—	1	▲ deputy, when firing a gunpowder shot, used too short a "touch," and the shot went off before he could get out of the way. Off work 3 days.
" 22nd	21	West Wylam ...	Stone drift	2	1	The three men were engaged in driving a stone drift, and at the time of the explosion the hewer was standing in the line of fire, his bobbin cartridge having exploded. What was actually being done at the time, or how the ignition took place, it is impossible to say, as the survivor declined to give evidence; but there is every reason to suppose that one of the deceased, at the time, was attempting to force the cartridges into the hole. At the inquest, the jury, after consultation, returned a verdict that "the deceased died from the effects of burns, resolved through an explosion of powder, but that there was not sufficient evidence to show how this was brought about."

APPENDIX C.—Continued.

Date.	No.	Name of Colliery.	Name of Seam.	No. Killed.	No. Injured.	Cause.
Aug. 27th	22	East Tanfield	Busty	—	1	When leaving his place after lighting a gunpowder shot the man ran against a tub, and his light being knocked out, he could not get away in time. Off work 7 days.
Sept. 6th	23	Maud	Bensham	—	1	Premature explosion of a gunpowder shot in consequence of the man having improperly nipped off part of the "touch" of his squib. Off work 21 days.
" 9th	24	Maud	Low Main	—	1	An exactly similar case to the preceding one, the shot having gone off prematurely for the reason there given. Off work 21 days.
" 13th	25	East Holywell	Low Main	—	1	A deputy on his rounds came to a place where another deputy had lighted up a gunpowder shot, which exploded as he was passing. It is plain that there had been gross carelessness, as in previous occasions should have been taken to see that the approach of anyone after the shot was ready for firing. Such an accident as this ought to be impossible. Off work 42 days.
Oct. 13th	26	South Medomsley	Low Hutton	—	1	Premature explosion of gunpowder shot, owing to the squib being too short. Off work 49 days.
" 28th	27	Dudley	Low Main	—	1	A man approached, unobserved, a place where a gunpowder shot had been lighted up, and was struck by a flying stone. The remarks with reference to accident No. 25 apply equally to this case.
Nov. 16th	28	Church	Yard	—	1	A gunpowder shot was fired in a certain place, which blew through into another working, injuring the man who was engaged there. The accident was due entirely to the neglect of the rules. Off work 14 days.
" 21st	29	Shire Moor	Bensham	—	1	A man was returning to his shot, thinking it had missed fire, when it went off, causing slight injuries. Gunpowder. Off work 7 days.
Dec. 16th	30	Newburgh	Princess	—	1	Forcing a cartridge into a hole too small to receive it, when it exploded. Another breach of rules. Gunpowder. Off work 43 days.
" 19th	31	South Medomsley	Busty	1	—	A heaver, when leaving his work, and on the road to the pit-bottom, was suddenly seen to be in flames, and it transpired afterwards that a pound of compressed gunpowder, which he was carrying in his coat pocket had by some means become ignited, resulting in this fatal accident. The heaver was killed later on, and his coat was examined, that he had a round pound of the same explosive in another pocket. Gunpowder are supposed to be used at this pit, and only three weeks before this accident, a man was prosecuted and fined for taking loose cartridges into the pit.
Totals				7	29	

APPENDIX D.—STATUTORY RULES AND ORDERS, 1896, No. 1105.—THE
EXPLOSIVES IN COAL MINES ORDER, 1896.

Whereas by section 6 of the Coal Mines Regulation Act, 1896, it is enacted that a Secretary of State, on being satisfied that any explosive is, or is likely to become, dangerous, may by order prohibit the use thereof in any mine or in any class of mines either absolutely or subject to conditions :—

I hereby, in pursuance of the power conferred on me, by the aforesaid section, make the following order :—

1. *Absolute Prohibition of Certain Explosives in Unsafe Mines.*—In all coal mines of the following classes, viz. :—

- (1) All coal mines in which inflammable gas has been found within the previous six months, and
- (2) All coal mines which are not naturally wet throughout, on and after the 1st July, 1897, the use of any explosive, other than a permitted explosive, as hereinafter defined, is absolutely prohibited in the roads, and on and after the 1st January, 1898, the use of any explosive, other than a permitted explosive, is absolutely prohibited in every part of the mine.

2. *Conditional Prohibition of Other Explosives in Unsafe Mines.*—In all such coal mines as aforesaid, on and after the first day of January, 1898, the use of permitted explosives is prohibited unless the following conditions are observed :—

- (a) Every charge of the explosive shall be placed in a properly drilled shot hole and shall have sufficient stemming not in any case less than 9 inches.
- (b) The apparatus or method, whether electrical or otherwise, used to ignite the charge in the firing of any shot shall, so far as is reasonably practicable, be incapable of igniting inflammable gas or coal dust.
- (c) Every charge shall be fired by a competent person appointed in writing for this duty by the manager of the mine, and not being a contractor for any work in the mine involving the use of explosives, nor a person paid by such contractor, nor a person whose wages depend on the amount of mineral to be gotten.
- (d) Each explosive shall be used in the manner and subject to the conditions prescribed in the schedule hereto, or in any schedule substituted therefor by any future order.

Provided that nothing in this order shall prohibit the use of a safety fuze in any mine in which no inflammable gas has been found within the previous six months.

3. *Conditional Prohibition of all Explosives in Main Roads.*—In every coal mine on and after the first day of July, 1897, the use of any explosive is prohibited in the main haulage roads and in the main intakes unless the following condition is observed, viz. :—That all workmen have been removed from the seam in which the shot is to be fired and from all seams communicating with the shaft on the same level, except the men engaged in firing the shot, and such other persons, not exceeding 10 in number, as are necessarily employed in attending to the ventilating furnaces, steam boilers, engines, machinery, winding apparatus, signals, or horses, or in inspecting the mine.

4. *Application of Order.*—This order shall not apply to mines of clay or stratified ironstone, nor to shafts in course of being sunk from the surface.

Where a mine contains several separate seams this order shall apply to each seam as if it were a separate mine : Provided that several seams communicating with the shaft at the same level shall be deemed to be one seam.

5. *Definitions.*—In this order the term “permitted explosives” means such explosives as are named and defined in the schedule hereto or in any schedule substituted therefor by any future order: Provided that where the composition, quality, or character of any explosive is defined in such schedule, any article alleged to be such explosive which differs therefrom in composition, quality, or character, whether by reason of deterioration or otherwise, shall not be deemed to be the explosive so defined.

The term “road” includes all roads of any description communicating between the shaft or outlet and the working coal face.

The term “main haulage road” means a road which has been, or for the time being is, in use for moving trams by steam or other mechanical power.

6. *Citation.*—This order may be cited as the Explosives in Coal Mines Order, 1896.

Home Office, Whitehall, December 19th, 1896.

M. W. RIDLEY,
One of Her Majesty's
Principal Secretaries of State.

Schedule.

LIST OF PERMITTED EXPLOSIVES.

Ammonite, consisting of ammonium nitrate not more than 89 parts and not less than 87 parts, uniformly incorporated with thoroughly purified di-nitro-naphthalene not more than 13 parts and not less than 11 parts, and with no other ingredient.

Provided that the explosive be used only in the form of blasting cartridges, not containing their own means of ignition, and that every such cartridge be contained or enclosed in a thoroughly waterproof case.

Provided also that the explosive be fired only by means of a detonator or electric detonator fuze of not less strength than that known as No. 7, containing of explosive of the fifth (fulminate) class not less than 23 grains.

Ardeer Powder, consisting in every 100 parts of the finished explosive, of not more than 34 parts and not less than 31 parts of thoroughly purified nitro-glycerine, with not more than 13 parts and not less than 11 parts of kieselguhr, with not more than 51 parts and not less than 49 parts of magnesium sulphate, and with not more than 6 parts and not less than 4 parts of potassium nitrate with or without the addition of not more than $\frac{1}{2}$ part of ammonium carbonate, and not more than $\frac{1}{4}$ part of calcium carbonate and with no other ingredient, the whole being uniformly incorporated and of such character and consistency as not to be liable to exudation.

Provided that the explosive shall be fired only by means of a detonator or electric detonator fuze of not less strength than that known as No. 3, containing explosive of the fifth (fulminate) class not less than eight grains.

Provided also that the explosive shall not be fired in the frozen condition.

Bellite No. 1, consisting of ammonium nitrate not more than 81 parts and not less than 79 parts uniformly incorporated with thoroughly purified meta-di-nitro-benzol not more than 21 parts and not less than 19 parts, and with no other ingredient.

Provided that the explosive be used only in the form of blasting cartridges not containing their own means of ignition, and that every such cartridge be contained or enclosed in a thoroughly waterproof case or wrapper.

Provided also that the explosive shall be fired only by means of a detonator or electric detonator fuze of not less strength than that known as No. 7 containing of explosive of the fifth (fulminate) class not less than 23 grains.

Bellite No. 3, consisting of ammonium nitrate not more than 94 parts and not less than 92 parts uniformly incorporated with thoroughly purified meta-di-nitro-benzol not more than 8 parts and not less than 6 parts, and with no other ingredient.

Provided that the explosive be used only in the form of blasting cartridges not containing their own means of ignition, and that every such cartridge be contained or enclosed in a thoroughly waterproof case or wrapper.

Provided also that the explosive shall be fired only by means of a detonator or electric detonator fuze of not less strength than that known as No. 6, containing of explosive of the fifth (fulminate) class not less than 15 grains.

Carbonite, consisting in every 100 parts of the finished explosive, of not more than 27 parts and not less than 25 parts of thoroughly purified nitro-glycerine, with not more than 36 parts and not less than 30 parts of barium nitrate and potassium nitrate, or either of them, and with not more than 43 parts and not less than 37 parts of woodmeal with or without not more than $\frac{1}{2}$ part of sulphuretted benzol, and not more than $\frac{1}{2}$ part of sodium carbonate and calcium carbonate, or either of them and with no other ingredient, the whole being uniformly incorporated and of such character and consistency as not to be liable to exudation.

Provided that the explosive shall be fired only by means of a detonator or electric detonator fuze of not less strength than that known as No. 6, containing explosive of the fifth (fulminate) class not less than 15 grains.

Provided also that the explosive shall not be fired in the frozen condition.

Dahmenite A, consisting in every 100 parts of the finished explosive, of not more than 93 $\frac{1}{2}$ parts and not less than 91 parts of ammonium nitrate, with not more than 6 $\frac{1}{2}$ parts and not less than 4 parts of naphthalene, and with not more than 2 $\frac{1}{2}$ parts and not less than 1 part of potassium bichromate, and with no other ingredient, the whole being uniformly incorporated.

Provided that the explosive be used only in the form of blasting cartridges not containing their own means of ignition, and that every such cartridge be contained or enclosed in a thoroughly waterproof case or wrapper.

Provided also that the explosive shall be fired only by means of a detonator or electric detonator fuze of not less strength than that known as No. 7, containing explosive of the fifth (fulminate) class not less than 23 grains.

Electronite No. 2, consisting of ammonium nitrate not more than 91 parts and not less than 90 parts, uniformly incorporated with not more than 10 parts and not less than 9 parts of woodmeal and starch, and with no other ingredient.

Provided that the explosive be used only in the form of blasting cartridges not containing their own means of ignition, and that every such cartridge be contained or enclosed in a thoroughly waterproof case or wrapper.

Provided also that the explosive be fired only by means of a detonator or electric detonator fuze of not less strength than that known as No. 6, containing of explosive of the fifth (fulminate) class not less than 15 grains.

Kynite, consisting in every 100 parts of the finished explosive of not more than 27 parts and not less than 25 parts of thoroughly purified nitro-glycerine, with not more than 36 parts and not less than 30 parts of barium nitrate and potassium

nitrate, or either of them, and with not more than 43 parts and not less than 37 parts of woodmeal, with or without not more than $\frac{1}{2}$ part of sulphuretted benzol, and not more than $\frac{1}{2}$ part of sodium carbonate and calcium carbonate, or either of them, and with no other ingredient, the whole being uniformly incorporated, and of such character and consistency as not to be liable to exudation.

Provided that the explosive shall be fired only by means of a detonator or electric detonator fuze of not less strength than that known as No. 6, containing explosive of the fifth (fulminate) class not less than 15 grains.

Provided also that the explosive shall not be fired in the frozen condition.

Roburite No. 3, consisting in every 100 parts of the finished explosive of not more than 89 parts and not less than 86 parts of ammonium nitrate, with not more than 13 parts and not less than 9 parts of thoroughly purified di-nitro-benzol, with or without not more than 2 parts of chloro-naphthalene containing of chlorine not more than 1 part, and with no other ingredient, the whole being uniformly incorporated.

Provided that the explosive be used only in the form of blasting cartridges not containing their own means of ignition, and that every such cartridge be contained or enclosed in a thoroughly waterproof case or wrapper.

Provided also that the explosive shall be fired only by means of a detonator or electric detonator fuze of not less strength than that known as No. 6, containing explosive of the fifth (fulminate) class not less than 15 grains.

Westfalite, consisting of ammonium nitrate not more than 96 parts and not less than 84 parts, uniformly incorporated with gum-lac soluble in alcohol not more than 6 parts and not less than 4 parts, and with no other ingredient.

Provided that the explosive be used only in the form of blasting cartridges not containing their own means of ignition, and that every such cartridge be contained or enclosed in a thoroughly waterproof case or wrapper.

Provided also that the explosive shall be fired only by means of a detonator or electric detonator fuze of not less strength than that known as No. 8, containing explosive of the fifth (fulminate) class not less than 30 grains.

Provided that in addition to the marking on the outer package containing any of the above explosives, enjoined by an order of Secretary of State made under section 40 of the Explosives Act, 1875, and in force for the time being, such outer package shall bear the words "as defined in the list of permitted explosives," together with the date of this order. And, further, that each inner package shall be marked with the words "permitted explosive," and also with the name of the explosive, the date of manufacture, and the nature and proportion of the ingredients.

The PRESIDENT said that the members were much obliged to Mr. Hall for bringing the subject of explosives before them. It was one of the most important subjects under the consideration of the coal trade at the present time, and if anything could be done for the saving of life in mines, it would be speedily adopted. Mr. Hall stated that the cost of using safety-explosives was 0·81d. per ton higher than it was under the

old system of using blasting-powder. Was this calculation based on the present system of using safety-explosives, or on the future system which would be adopted when the Secretary of State's order came into effect? He thought that the requirements of the order were much more stringent than those now in force in West Lancashire. He was of opinion that the order would entail a larger cost than 0·31d. per ton, as between the use of safety-explosives and blasting-powder. If the workmen had to be taken out of the mine for every shot fired, he thought that the cost would be prohibitory to the working of many mines, and in large collieries it could not be carried out. The results recorded in Mr. Hall's paper as to the number of persons killed from explosions of blasting-powder might be misleading, as they depended upon the number of shots fired for the production of the same weight of coal. In the Northumberland inspection-district 55,000 persons were employed underground, and in West Lancashire and North Wales 46,000 persons, but the members had not been informed as to the number of shots fired in each district, consequently it was impossible to make true comparisons until these details were supplied.

With respect to the number of persons killed by falls of stone, Mr. Hall compared the Northumberland inspection-district with the Durham inspection-district, but if they took the proportion of persons killed in West Lancashire by falls of stone for the same number of persons employed, the results were very much greater. In West Lancashire safety-lamps were largely used; in the Northumberland inspection-district half the men worked with candles and half with safety-lamps; and half the coal was produced by workmen using candles. The paper would have been more valuable if it had given details as to the lives lost, workmen employed underground, production of coal, and shots fired in mines worked with candles compared with those worked with safety-lamps.

Mr. A. L. STEAVENSON (Durham) said that there could be no doubt that Mr. Hall's paper formed a most valuable contribution to that stock of knowledge which it was the duty of all mining engineers to accumulate during the present year, and that it should afford immense encouragement to those who were prepared to strain every nerve to compass once for all the total abolition of blasting-powder from coal-mines. The two main facts, (1) as to no increase of small coal, and (2) an increase of cost of only $\frac{1}{3}$ d. per ton, were such as he hardly dared to expect, although in the matter of cost his own private estimate, having regard to the total

output of a colliery, was under 1d. per ton; but upon this point he was keeping a perfectly open mind until he was in possession of some independent facts.

It would be remembered by those members who had studied the early volumes of the *Transactions of The North of England Institute of Mining and Mechanical Engineers*, an institution originated for the express purpose of accident prevention, that Mr. Nicholas Wood said in his inaugural address:—

To-day, we are entering upon an undertaking which may be of essential utility to the important interests entrusted to our charge, and which may be the means of averting some at least of those dreadful and deplorable catastrophes which have too often been felt with such disastrous consequences to the district, and to the sufferers, by their occurrence.*

After forty-five years or nearly half a century, the members are to-day in discussion upon a step more likely to accomplish the object so dear to the heart of the man who penned those lines than all the work accomplished by the mining institutes during that long interval of years.

Had this order been issued then, how many thousands of lives would have been spared, and what, therefore, should be the attitude of all of us—so deeply interested, either as owners or agents, as we are? It should undoubtedly be one of welcome, coupled with determined resolution to make it in all respects practicable and a success if possible. Let us look for a few moments at the grounds for it and the urgent needs for it, and where can we look in a better direction than in the numerous *Reports of H.M. Inspectors of Mines*? He would quote a few of their statements from the *Preliminary Report of H.M. Commissioners appointed to Inquire into Accidents in Mines, 1881*:—

Mr. F. Wardell said (reply 2,207) that “I would not allow powder [to be used] where lamps are used under any circumstances,” and (replies 2,211 and 2,212) “a shot” [is] “one of the worst forms of naked lights.”

Mr. T. Wynne said (reply 578) that “It is a perfect farce to have a light, a farthing rushlight, covered with gauze, and then to have a blast that reaches 30 yards along or more.”

Mr. R. Moore said (reply 1,812) that “wherever safety-lamps are used, I would prohibit blasting in coal.”

Mr. T. Cadman said (reply 3,394) that “where safety-lamps are required I certainly do not agree with blasting.”

Mr J. P. Baker stated (reply 4,573) that he “would certainly prohibit” [powder where safety-lamps are used].

* Vol. i., page 3.

Now let the members look for a moment at the claims which the opinions of H.M. Inspectors of Mines have upon our most serious attention. To begin with, they are mining engineers carefully selected after full enquiry as to fitness and experience, of well-known ability for their duties. They live each in one of the coal-mining centres. No sooner does an explosion occur than they hurry off, and from that moment until the last word of their *Report* has been written their undivided attention has been given to every detail of the accident, and above all men they have an experience such as no others can obtain. Let us therefore ascertain what impression has been left in these cases upon their minds.

Mardy, December 23rd, 1885.—Mr. Wales said that “in my opinion, there should be a legislative enactment to strictly prohibit the use of gunpowder or other explosives.”

Elmore, December 2nd, 1886.—Mr. T. Bell said that he “is informed . . . that since this explosion, . . . the use of gunpowder has been discontinued at all the collieries belonging to the Hetton Coal Co.”

Park Slip, August 26th, 1892.—Messrs. J. T. Robson and W. N. Atkinson reported that “no shots should be fired in the mine, except by one or more of the officials who shall have more complete control over the explosives, and that the use of gunpowder and dynamite be prohibited.”

Albion, June 23rd, 1894.—Messrs. J. T. Robson, H. Hall, and Jos. S. Martin were of opinion “that blasting with gunpowder and other flaming explosives should be abolished altogether in the working of such mines.”

Malago Vale, March 15th, 1895.—Mr. J. S. Martin said that “in concluding this report, the second which I have had occasion to make within three weeks upon accidents occurring from blasting with powder, and in both of which cases it has only been through the fact of blasting having been done with a limited number of men in the mine that the loss of life has not been very much larger, I beg to again express my opinion with increased emphasis that the total abolition of powder in coal-mines is desirable, and that where blasting is required it should be limited to the use of the most approved safety-explosives fired by electricity, with further restrictions according to circumstances.”

Brancepeth, April 13th, 1896.—Mr. R. D. Bain said that “the lesson to be learnt from Camerton and Timsbury and this explosion is that the use of gunpowder on main haulage-roads is attended with considerable risk and danger. To ensure safety in a dry mine, none but high explosives

should be used, and these, too, with every precaution. Both the English and German experiments prove that gunpowder and nitro-glycerine compounds have the lowest factor of safety of any explosives in the market, and their use should be prohibited in all dusty and fiery mines and on all main haulage-roads in coal-mines unless they are absolutely wet."

In the safe collieries, it is gravely proposed that the Secretary of State's order should be left to the inspectors to enforce, and it was asserted that there were a large number of collieries where it was quite unnecessary.

He might remark that Brancepeth was a shallow mine, a non-gaseous mine, and reckoned a safe one. In the *Report* on the Brancepeth explosion of April 13th, 1896, it is stated that, "It was . . . proved by evidence . . . that the pit was considered by all responsible persons as non-gaseous, and not a fiery pit, and, indeed, in that respect a very safe pit. Mr. Grieves said that until 1882, naked lights only had been used in every part." Now, if Brancepeth was held to be a safe pit and was not, where are they to be found? No doubt every mining agent about that place believed that it was so, just as much as these engineers who are now wanting the Secretary of State to have them excused. If Brancepeth had been amongst those excused, who then would have been responsible?

He was of opinion that powder-shots should no longer be fired in the roads, as all the recent serious explosions had occurred through the use of blasting-powder in dusty roads. The order, however, contemplated the firing of only one shot. This in a large colliery was not sufficient. They must ask the Secretary of State to extend the number of shots, because if a large colliery had five or six main roads it might be necessary to fire shots in greater number than the order contemplated.

There was no doubt that, where the miner had to deal with hard stone, quick explosives were infinitely better than blasting-powder. He had had thirty-five years' experience in the iron-ore mines of Cleveland, where they were producing 3,000 or 4,000 tons a day, and used large quantities of blasting-powder. The stone was of a mild nature, in which blasting-powder could do its work better, but in the case of hard stone, quick explosives or safety-explosives proved the best for use. He urged the members to wait, except with regard to shot-firing, until September or October, 1897, when, having got abundant experience they could meet and make up their minds as to the extent to which it was desirable to ask the Secretary of State to mitigate his order. The Secretary of State was a descendant of a family which had been wellknown for at least 150 years, and held in the highest honour. If by this order the present

holder of the title should be the means of mitigating the severity of mine explosions, he would have earned a greater title to their gratitude than had been deserved by any of the long line of his predecessors.

Mr. JOSEPH DICKINSON (late H.M. Chief Inspector of Mines, Manchester) said that, although it was not of much importance, the claim set up for West Lancashire as being the cradle of what were termed safety-explosives scarcely commended itself to his mind. He would rather say that they originated with the water-cartridge and gelignite at Darcy Lever colliery in East Lancashire; and that the cartridges were still in use, although restricted by the large shot-hole which they required.

Mr. Hall's paper treated of two subjects, the cost and efficiency of safety-explosives as compared with blasting-powder, but under the head of efficiency it expanded into the question of safety-lamps as compared with candles for lighting.

As to cost, the writer deduced, from elaborate tables and his own wide experience, an increase of nearly 1d. per ton in getting coal with high explosives, but he qualified it somewhat by a saving in the item of stonework. He also found, rather to his surprise, that with both high and low explosives the tables showed the output of equal proportions of round coal. The actual cost for the respective explosives he reckoned at 0·61d. with blasting-powder, and 0·92d. with safety-explosives; or about one-half more for high explosives.

Every person who knew the worthy writer of the paper will credit him with implicit fairness in analysing the result of his researches. He candidly admitted the difficulty of apportioning the relative costs and proportions from the tables. It may therefore be that consequent on the changing to safety-explosives, less of the explosive may have been used in the shots, and more work done with the pick. Or, possibly, too much may have been used, and thus have affected the conclusion.

If any part of the conclusion has been drawn from "Appendix C.—List of Explosions of Gunpowder, etc., in the Newcastle-upon-Tyne Mines Inspection-District, 1895," it will require scrutiny: the 81 explosions therein recited admit of division into classes, and each class admits of subdivision, which may alter the view. Nearly the whole of these classes appear to be common to all accidents with explosives, namely, want of sufficient care in handling. The list, therefore, if it showed anything definite was against blasting with any kind of explosive, and favoured giving up entirely this labour-saving adjunct.

As to the question of efficiency, a case was supposed to be made out by comparing districts suitable for the required proofs. The allegation of

decadence of skill and care in Northumberland (his native county) was almost enough to resuscitate, in protest, the late revered Messrs. John Buddle, Nicholas Wood, Thomas Emerson Forster, and other mining celebrities, who so long kept the northern counties in the van of progress.

Altogether, the paper set forth that mine-owners had not been severely dealt with during the last twenty years. Prior to that time, however, they were undoubtedly roused up considerably, the amount of cost of legislation being often roughly reckoned at 6d. per ton. That rousing was justly required of some of the mine-owners, and it had been fully compensated by the succeeding increased efficiency, safety from accidents, and improved health of the miners. In this East Lancashire district, during his forty-one years' supervision as H.M. Inspector of Mines under existing requirements, through improvements effected by those acting in the management, this rousing influence diminished for the last five years the accidents 54 per cent., and the deaths from the accidents 74 per cent.; in this diminution were included explosions of fire-damp, which came down from high numbers to less than an average of one yearly.

Should the further powers now about to be introduced be requisite, 1d. per ton additional does not appear heavy. Worked out, however, on the whole output it comes to the considerable amount of £790,000 annually, which should not be spent needlessly; or, if taken at one-third of the output, it was over £268,000. If really required, it would doubtless, as hitherto with the larger demands, obtain loyal acquiescence.

Mr. J. J. PREST (Stoke-upon-Trent) thought that the footnote (a) to Table I. of Mr. Hall's statistics afforded a little light on the efficiency of safety-explosives as compared with blasting-powder for the production of round coal: the manager stated that "when we commenced to use high explosives, the bars were reduced from 1 inch to $\frac{3}{4}$ inch," showing very plainly, he thought, what that gentleman anticipated would be the effect of adopting high explosives for getting coal in place of blasting-powder: and that this anticipation was realized was shown by the fact that he was now only producing the same percentage of round coal with bars less than half their former width apart. Nevertheless, Mr. Hall based his arguments and deductions on the relative percentages of round and small coal obtained by the use of different explosives, when the natural results were neutralized by such expedients as the one quoted. Would any colliery manager assert that coal made over $\frac{3}{4}$ inch bar-screens would have the same market value as the coal made over 1 inch bar-screens? If not, then the difference in value must be placed to the account of the high explosive.

At two of the collieries under his charge, about 1 ton of ammonite was used per month, and he had no hesitation whatever in asserting that the production of slack was increased in consequence, and that the cost per ton for explosives was double what it was when blasting-powder was in use. The actual cost per ton of explosives for the production of black band ironstone was :—Blasting-powder and fuze, 0·910d. per ton ; ammonite, detonators, etc., 1·706d. per ton ; showing an increase of 0·796d. per ton.

Apart, however, from the increase of cost, and that was serious enough in these bad times, he considered that the most astonishing feature of the order was the removal of all workmen except 10 from the pit, whilst shot-firing was taking place on a main intake or haulage-road, even although a permitted explosive was being used : one would have expected that the Secretary of State or his advisers would have had sufficient faith in their permitted explosives to sanction their use under normal conditions of work. Pits working a double shift of men would have to lay one shift idle when this order comes into operation, so as to fire shots even in the face of main intake-airways or haulage-roads : and how anyone will ever be able to make a refuge-hole, engine-house, or take stone off the side of such a road in the future, unless, as he had said, one shift is laid idle for the purpose, he could not imagine ; and the effect of laying a shift of hewers off in an old pit is not difficult to understand. Then, again, why should 10 men be particularly called upon to risk their lives any more than 100 or a pit's crew ? Surely if it be dangerous for the latter, it was equally so for the former, and he would imagine that these 10 men would very soon appraise that risk at its proper monetary value.

Personally, he had no objection whatever to the general use of the permitted explosives ; but it must be under existing conditions of work, and without sending any workmen out of the pit.

Mr. W. COCHRANE (Newcastle-upon-Tyne) endorsed Mr. Steavenson's remarks with respect to the use of safety-explosives in Cleveland ironstone-mines, where in practice they were an utter failure. Blasting-powder was the only explosive that yielded satisfactory results, and if its use was prohibited in coal-mines, perhaps eventually the order might be extended to ironstone-mines. It seemed to him that the conditions of some collieries were similar to the conditions of the Cleveland ironstone-mines. Mr. Hall stated in his paper that it was admitted by working miners that the fumes of safety-explosives were not dangerous. From correspondence in newspapers he had recently read from Northumberland and Durham miners, he thought Mr. Hall would have to admit that

miners generally had not admitted that the fumes were not dangerous. He regretted that the author should have described the methods of mining in Durham and Northumberland as "antique" and "primitive." Not satisfied with his statement as to their use of safety-explosives, he emphasized it by abandoning the object of his paper. He (Mr. Cochrane) could not see in what manner falls of roof had to do with the "cost and efficiency of safety-explosives." If, in addition to comparing the Northumberland and Durham mines inspection-districts, Mr. Hall had taken West Lancashire, he would have found it in a backward position. The figures were:—Northumberland, 54,932 persons employed underground, 179 deaths from falls; Durham, 54,010 persons employed underground, 165 deaths from falls; and West Lancashire, 46,131 persons employed underground, 229 deaths from falls. He would like the author to compare the three districts, and possibly he might modify his inference as to the two former districts.

Mr. E. B. WAIN (Stoke-upon-Trent) said that in the figures given in Table I., Mr. Hall did not state whether the expenditure on explosives was simply for coal-getting or for all operations connected with coal-getting. In most longwall collieries no explosive was used for coal-getting, and the ripping or stone-work absorbed almost the whole of the explosive used. In such cases it was almost impossible to make comparison of costs and percentages of round coal. He was much surprised to hear Mr. Hall state, after the experience which he must have had with high explosives, that no more slack was made. He noticed that most of the collieries quoted in Table I. were working hard coal. It was possible in hard coal-seams that safety-explosives might be used without much loss of round coal, but he ventured to say that, in some of the tender thick coal-seams of North Staffordshire, a considerably increased proportion of small coal was made when safety-explosives were used.

He thought that Mr. Hall rightly emphasized the necessity for explosives being used by workmen specially appointed for the purpose, a system which was now in force in the North Staffordshire district; and with the excellent deputy system in force in the North of England there seemed to be no reason why deputies should not also act as shot-lighters.

In the Northumberland mines inspection-district (he spoke under correction), it seemed to be the practice for the hewer to fire his own shots; in the West Lancashire and North Wales district, it was the custom for trained workmen to fire the shots, and the probability was that the comparison shown in Table II. was favourable to the latter districts simply and solely on the ground that the trained workman, who

was appointed to fire the shots and examine the working-places, was more careful in handling the explosive than the miner, who was a contractor.

Mr. G. BLAKE WALKER (Barnsley) said that high explosives had been used during the past seven years at Wharnccliffe Silkstone colliery. Mr. Wain had said that the use of explosives in longwall collieries was limited in a great measure to stone-work, but there were collieries which had been worked with blasting-powder, and one of these was the parkgate seam of the Wharnccliffe Silkstone colliery. Blasting-powder was previously provided by the workmen themselves, but the owners recognized that it was in the interests of safety that a safety-explosive should be used in place of blasting-powder. Roburite was substituted, and in the past seven years there had been no enhanced cost as between roburite and powder, because the workmen in both periods bought their own explosive, and the lessened quantity of roburite used had met the increased cost per pound. The company had sustained, what at first sight might be considered a serious loss, from having to provide detonators. Three shots were fired for each pound of roburite, and the actual enhanced cost was represented by the cost of three detonators. There had not been during that time any serious complaint as to the fumes being injurious. He had observed where the ventilation had become slack by accident, the presence of a vapour with a peculiar smell, and had no doubt, if they were compelled to remain long in it, that it might produce giddiness, but with efficient ventilation, the fumes soon mixed with the air and passed away.

Mr. W. J. ORSMAN (Wigan) said that he should like to say a few words with regard to the statement that miners and medical men upheld the view that the fumes given off by safety-explosives were more dangerous than the fumes of blasting-powder. When safety-explosives were introduced into the district of Lancashire, the question of fumes was at once raised. A committee was appointed, consisting of Prof. H. B. Dixon, Dr. N. Hannah, and Dr. C. J. Mouncey, and they reported that the fumes given off by safety-explosives were perfectly innocuous. He did not allude to explosives of the nitro-glycerine type, which might be dangerous, but to the nitrate-of-ammonium explosives.

Mr. M. DEACON (Sheepbridge) said that Mr. Hall had based his conclusions on "the light of present knowledge," but he (Mr. Deacon) thought that the present knowledge of explosives was not what it ought to be, and he ventured to suggest that the Secretary of State should undertake experiments on a larger scale than had been so far undertaken,

before deciding which of the permitted high explosives could be safely used. Mr. Hall stated that 62·2 per cent. of round coal was obtained with powder and 62 per cent. with safety explosives. He should like to know whether the whole of the slack coal was sent out of the mine, or whether (if it was gobbled) there was any reduction in the number of tons per acre produced over the periods during which the tests were made. He had made a number of practical tests in various coal-seams with several kinds of high-explosives as compared with blasting-powder, for the purpose of ascertaining the effect in the production of slack coal. All these experiments, which were very numerous—about 100 in all, were made in the soft coal-seams of Derbyshire, and with the use of high-explosives the percentage of slack coal was 5 to 6 per cent. higher than when blasting-powder was used under similar conditions. Instead of 1d. per ton being sufficient to cover the enhanced cost, an increase of 5 per cent. of slack coal would alone entail a reduction in the average selling price of about 3d. per ton in the case of an average colliery. This cost, as well as the 1d. per ton represented by Mr. Hall as the cost of shot-firing and explosives, must be reckoned. He was satisfied that, in tender coal-seams with high-explosives, there would be a considerable reduction in the profits or increase in the losses, probably to the extent of 3d. or 4d. per ton as against blasting-powder.

Mr. W. N. ATKINSON (H.M. Inspector of Mines, Newcastle-under-Lyme) remarked that Mr. Hall's estimate of 1d. per ton was much nearer the mark than some of the statements which had been recently going the round of the newspaper press. It must be remembered, however, that even $\frac{1}{2}$ d. per ton on an output of 300,000 tons a year amounted to £625 per annum—a sum not to be despised in these days of keen competition. It was on the ground of safety alone, however, that it was thought necessary to formulate new regulations as to the use of explosives. There were two considerations to which he should direct attention: first, the fact that the use of safety-explosives had already been voluntarily and exclusively adopted at a large number of extensive collieries, and also that experiments and practical experience bore testimony to their greater safety, so far as explosions of gas and coal-dust were concerned. The second point was that most of the recent explosions had been in mines previously held to be safe so far as gas or dust was concerned. Such explosions had occurred within the last three or four years: at Camerton and Tinsbury, 9 lives lost; Thornhill, 139; Blackwell, 7; Micklefield, 63; and Brancepeth, 20; a total of 238 lives; and without doubt had cost many thousands of pounds to the owners of those collieries. These observations

he thought had a bearing on the necessity of some further attempt to prevent explosions of gas or coal-dust. Mr. Cochrane need have no fear that the order, or some similar order, might in future be extended to ironstone-mines until some serious explosion occurred in those mines. There had been several investigations by men of undoubted ability as to the fumes of safety-explosives, and they were of opinion that the fumes were practically harmless. He did not altogether agree with the conclusions of these committees, because he believed that the fumes of all explosives were dangerous under certain conditions. The fumes of any explosive containing nitro-glycerine were likely to be dangerous, if inhaled before being plentifully diluted with air. He had been informed by the manager of a large colliery in North Staffordshire where a safety-explosive had been substituted for blasting-powder that he (the manager) thought the cost was no more, because a smaller number of shots were required. He believed that in the Midland districts explosives were used rather extensively, both for getting coal and ripping roads in longwall working.

Mr. HAROLD BONSER (Leeds) remarked that the order of the Secretary of State required in the case of carbonite that detonators of not less strength than No. 6 should be used. He was of opinion that this portion of the order should be amended as a No. 3 detonator, containing only one-half of the fulminate in a No. 6 detonator, would detonate carbonite efficiently, and on no account should a detonator of greater strength than a No. 5 be used with carbonite.* Several speakers had alluded to the incidence of the new order (notably Mr. A. L. Steavenson), and he suggested that if the Coal Mines Regulation Act of 1887 and its definition of what should be considered as constituting a separate mine, could be retained under the new order, many of the chief objections to the order would be removed—notably in the case of tunnels and stone-headings having a separate intake from and return airway into a main intake and return airway—so that in wet headings and tunnels gelignite could still be used as the most powerful and suitable explosive for that kind of work.

* Detonators usually contain fulminate of mercury or a mixture of the same with chlorate of potassium, and occasionally other substances. The usual sizes, etc., are:—

No. 1	detonators	contain	0·30	grammes	or	4·6	grains.
No. 2	„	„	0·40	„	„	6·1	„
No. 3	„	„	0·54	„	„	8·3	„
No. 4	„	„	0·65	„	„	10·0	„
No. 5	„	„	0·80	„	„	12·3	„
No. 6	„	„	1·00	„	„	15·4	„
No. 7	„	„	1·50	„	„	23·1	„
No. 8	„	„	2·00	„	„	30·8	„

Mr. N. R. GRIFFITH (Ruabon) said that he could afford a little further information as to No. 1 colliery in North Wales. Fixed bar-screens were used in the days of wide-gauge and blasting-powder, while jigging-screens were now in use. With the fixed bar-screens a considerable quantity of small coal passed with the large over the top of the screens, whilst with the jigging-screen every particle of small coal passed through the screens, and therefore the alteration of the screens had not made a difference precisely in proportion to the widths between the bars. The coal was more valuable when passed over the narrower screens, as the coal delivered over the moving screens and picking-belts was delivered in a more marketable, cleaner, and better state than was possible with the wider fixed bar-screens. At first, the tendency of the workmen was to use too much of the safety-explosive in the shot-holes. It was a fact that a considerable number of mining engineers who now used blasting-powder expressed considerable disinclination to use safety-explosives in the future, but not a single case had come to his knowledge in which an engineer who had abandoned blasting-powder in favour of safety-explosives had expressed a wish to revert to the use of blasting-powder. He was also of opinion that workmen who had been using safety-explosives for some time did not want to go back to blasting-powder. The commercial disadvantage of the use of safety-explosives was very trifling, and he thought that Mr. Hall had stated it at about the correct figure. From his own experience he would advise engineers who were contemplating the use of safety-explosives not to attempt to thrust their use too suddenly upon the workmen. If safety-explosives were introduced gradually they would ascertain which explosive was best adapted to the coal in each case, as probably some explosives were more suitable for hard and some for soft coal.

Mr. JOHN GERRARD (H.M. Inspector of Mines, Manchester) said that whatever might be thought of Mr. Hall's remarks with regard to the use of blasting-powder in the Northumberland inspection-district and the use of safety-explosives in West Lancashire, the members should all thank Mr. Hall for the pains and trouble that he had taken in preparing his paper. Mr. Hall had given the members figures supplied to him by owners of the various mines, and not mere estimates or opinions. He believed that East Lancashire was in entire accord with West Lancashire as regarded the use of safety-explosives. In time, with fuller experience of the use of safety-explosives, it would be found whether Mr. Hall had overestimated the effects of the use of safety-explosives upon the merchantable value of the coal, and he believed that it would be

less serious than Mr. Hall had stated. In East Lancashire, there were 19,000 persons employed underground where safety-explosives were in use entirely and solely for working coal or stone; 300 were employed where the water-cartridge was used, and 2,200 were employed underground where no explosive whatever was used, making 21,500 persons employed underground in mines where blasting-powder was not used. There were 8,400 persons employed in mines using safety-lamps where blasting-powder was used, and 1,000 in mines where candles were used with blasting-powder. A large proportion of the persons employed in mines were using safety-explosives, and the number was increasing. He believed that of the 8,400 persons employed in mines using safety-lamps and blasting-powder, in four months' time three-quarters of the number would be using safety-explosives. In East as well as West Lancashire, experience had been gained with regard to safety-explosives, and with Mr. Griffith he did not know of a single colliery where the use of blasting-powder had been resumed. Much of the success depended upon the weight of safety-explosive used in the charge. He regarded the distribution of detonators to the colliers generally with dismay, as he considered it was essential that they should be placed in the hands of responsible workmen. He had not the slightest doubt that deleterious fumes were produced from the use of explosives. On Monday last, he went into working-places immediately after the firing of five shots of a safety-explosive, and he experienced objectionable fumes; on the same day he went into a place where 4 ounces of blasting-powder had been fired and found that the fumes were ten times more abundant. It was wise to recognize that all explosives produced fumes. This explosives order was introduced to save life; it was therefore necessary that it be discussed temperately, and extreme cases or illustrations should be avoided.

Mr. GEORGE J. BINNS (Netherseal Colliery) said that, in calculating the difference between the cost per ton of blasting-powder and "permitted explosives," Mr. Hall appeared to have entirely failed to appreciate the effect of the "Explosives in Coal-mines Order, 1896," in certain cases. Take, for example, a colliery where horses are not used, and the tubs are run by means of engine-ropes, not only into, but along the faces of the stalls; where stone-drifts, worked by mechanical haulage, are continuously carried on; and where a large amount of rock-ripping is a daily necessity. In the first place, absolutely no shots could be fired in a coal-face where trams are moved by mechanical power, except under certain impracticable conditions, and the difference in cost to be estimated becomes that between explosives and no explosives, instead of that between blast-

ing-powder and the substitutes proposed to be allowed. In the second place, as stone-drifts are worked by engine-ropes, they are presumably under the same restrictions, and no blasting can be carried on except when "all workmen have been removed," etc.; and as practically all roads in the pit are "main haulage-roads," the same proviso applies to all rock-ripping. The estimate of the cost given by Mr. Hall, and the total absence of any reference to section 3 of the Coal-mines Order, confirmed the hypothesis that he had (as, apparently, had also the author of the order) entirely failed to take into consideration its effect on coal-mines where extensive rock-work was carried out, and where mechanical auxiliary haulage was in operation.

Mr. JEREMIAH HEAD (London) remarked that, if the cost of using safety-explosives did not exceed 1d. per ton more than the cost of using blasting-powder, no engineer would grudge the extra cost. Several engineers of great experience had expressed a belief that the cost would be much greater, and it behoved the members to consider seriously what the effect must be on the coal-trade, and the trades subsidiary to it, if the cost of coal was very seriously enhanced. In times past, Great Britain had the coal-trade of the world largely to herself, as well as the iron, steel, and other trades dependent upon it; but, as the members knew to their cost, that was no longer the case. At the Exchange at Middlesbro' on Tuesday last, the one subject of discussion was the incursion made upon the iron and steel trades of this country by their neighbours across the Atlantic. The iron and steel trades were built upon the coal-trade; and, considering the quantity of coal used in these trades, 1d. per ton on coal would amount to 2d., 4d., 6d., 8d., and upwards, per ton before the finished article was produced. Coal in the United States of America was produced at a much lower average cost than in this country; and they could not afford lightly to add to the cost of production in Great Britain if they wished to retain in their own hands the trades upon which the prosperity of the country was so largely founded. A few years ago his remarks might have been considered superfluous, because the bulk of the members did not then believe in the possibility of foreign competition in the iron and steel trades. But thousands of tons of iron and steel were now coming into the country, and were being sold at several shillings a ton below what they cost us to produce. It could not, therefore, be inappropriate to say a word of caution as to the necessity and importance of keeping down the cost price of coal, on which British industries so largely depended.

Mr. GEORGE BOOLE (Rainford), having had experience with roburite, said that there was no difficulty in using it in place of blasting-powder. He had no doubt there was a slight increase of cost in using safety-explosives instead of blasting-powder, but it was not so high as some engineers imagined. He had had great experience in the use of explosives, and should be very sorry to revert to the use of blasting-powder. With roburite there was less danger of blown-out shots, less danger of the coal being fired, and increased safety. It was very unfortunate that it should be proposed to stop the use of explosives altogether in mines, except in the case of only 10 workmen necessarily employed in the mine. If it were made compulsory to use safety-explosives, it should not be requisite to remove the whole of the workmen from the mine.

Mr. JOHN ROBINSON (St. Helens) said that he was in charge of collieries producing 1,500,000 tons of coal per annum. The use of roburite was introduced nine years ago and great difficulties were experienced. The difficulties of each pit were gradually overcome, and since that time it had been used successfully. He was under the impression that the percentage of round coal would be decreased, but after some months it was found that the percentage of round coal was unaltered. He had been surprised, when taking out particulars for Mr. Hall, to find that the cost of explosives last year as compared with ten years ago was almost the same, and that the round coal had only decreased by 1 per cent., although they were now working seams in which the coal was much softer. After nine years' experience of roburite he should be very sorry to be ordered to revert to blasting-powder.

Mr. J. W. HUTCHINSON (Bamfurlong) said that he had had over five years' experience of the use of safety-explosives. The cost had been a little more than $\frac{1}{2}$ d. per ton. The longwall was worked entirely by safety-explosives, but shots were not fired in the stone. Twelve thousand shots were fired last year, or about 40 per day, without one blown-out shot. The working of a seam, 2 feet 2 inches thick, had been abandoned when blasting-powder was used, owing to the percentage of round coal being so small, but now over 50 per cent. of round coal was produced with safety-explosives.

Mr. A. JACKSON (Collins Green) said that he had used safety-explosives for over seven years, and found no difference in the proportion of best coal to slack coal. He would not resume the use of blasting-powder under any circumstances.

Mr. J. H. MERIVALE (Broomhill Colliery) said that Mr. Hall had considered the use of safety-explosives under the heads of cost and safety, and had also introduced the question of safety-lamps, which at first sight appeared to have nothing to do with the Secretary of State's order. Mr. Hall had charged blasting-powder at 4d. per lb. Last year he had paid 2·81d. per lb., and he had a quotation for February of this year at 2·76d. per lb. Substituting the actual price at the present time, 2·76d., for the 4d. per lb., the price of a few years ago, on Mr. Hall's own figures, the cost of safety-explosives was more than double (2·19). Mr. Hall had ignored the cost of the shot-firers and safety-lamps altogether. What we had to compare was the cost under the present system, viz. :—Blasting-powder at say 3d., straws, naked lights, and no shot-firers ; with the system under the order, viz. :—Safety-explosives at say 10d. per lb., detonators, safety-lamps, and shot-firers. What would be the exact cost of the new system it was impossible to say until the experiment was made. This had not yet been done, and was not likely to be done voluntarily. Mr. Hall pointed out the difficulty of determining the actual effect of the change upon the percentage of round coal. This was evident from Table I. No. 4 colliery, for example, where the bars were unaltered, lost 5 per cent., and No. 9, on the other hand, in spite of the screen-bars being wider apart, gained 3 per cent. He believed that there would not be very much difference in the percentage of round coal at the screens ; but there would be a considerable loss by the time the coal reached the consumer. The coal was shattered by safety-explosives, did not carry well, and fell to pieces *en route*.

Mr. Hall quoted statistics showing that there had been fewer accidents from the use of explosives in West Lancashire than in Northumberland ; and argued that safety-explosives as used in West Lancashire were safer than blasting-powder used in Northumberland. But, before this opinion could be accepted, they must know the quantity of explosives consumed, or the number of shots fired in each district. Judging from Table I., the blasting-powder required to produce 1 ton of coal in Northumberland was considerably more than that required to get 1 ton of coal in West Lancashire. The tons of coal, too, produced were 83 per cent. more in Northumberland than in West Lancashire, and it followed that very many more shots were fired and that the accidents were necessarily more numerous.

He found at Broomhill colliery that approximately $7\frac{1}{2}$ million shots had been fired in twenty-five years. During that time, two men had been slightly burnt : one down the pit, and one in his house. There

had been no fatal accidents, and no accident of any kind when shot-firing. Though it might be a little difficult to improve upon this result, he was certainly of opinion with Mr. Hall that some of the safety-explosives, fired by experienced shot-firers, using electric detonators, were safer than blasting-powder fired by hewers, using straws or squibs. But the increase in safety was very small.

Mr. Hall showed that four times as many persons had been killed in Northumberland from explosions of gas as had been killed in West Lancashire. This was the fact, and the reason was probably as alleged by Mr. Hall. But he did not "look in vain for any compensating circumstances." There was the saving in cost; and he believed that the better light of the candle was a great safeguard from accidents from falls. Mr. Hall held a contrary opinion, but common sense showed that a good light was an advantage and must conduce to safety, and it was for Mr. Hall to prove that in this particular case his opinion was correct. He did not do so, for his comparison between the Durham and Northumberland mines inspection-districts was not to the point. There were quite as many candles used in the one as in the other district. Why did he not confine himself to the West Lancashire district, where lamps, he gathered from his paper, were used throughout? Here 229 persons had been killed from falls as against 179 in Northumberland. In other words, if statistics of this kind were of any value, safety-lamps should be introduced throughout in Northumberland; 2 lives per annum, now killed through gas, would be saved; at the cost of 19 per annum killed through falls. So far as he was aware, no facts had been collected from which any accurate deductions could be drawn as to the exact effect of the introduction of safety-lamps upon accidents from falls, and until this was done we were justified in believing that a good light was a safeguard, and should not be laid aside without good reason.

Mr. J. M. RONALDSON (H.M. Inspector of Mines, Glasgow) wrote that Mr. Hall's paper came at an opportune moment, when mining engineers were so much exercised as to the probable effect of the recently issued order by the Secretary of State with reference to explosives, and when the wildest conjectures were being hazarded regarding the increased cost that would be thereby entailed. Hitherto explosives such as those that are to be permitted by the order had been used to a very limited extent in Scotland, but the information that he had obtained on the subject as to increased cost and percentages of round coal coincided closely with the results given by Mr. Hall.

As the question of safety was considered in Mr. Hall's paper, under the head of efficiency, he would draw attention to one special kind of accident that prevailed in his district (West of Scotland), and which he almost despaired of seeing prevented, so long as naked lights and the use of blasting-powder were permitted. He referred to explosions of blasting-powder by sparks falling from the naked light placed on the caps of miners. Although a special rule prohibiting the naked light to remain on a workman's cap or near an explosive while handling it or charging a shot-hole had been in force for $2\frac{1}{2}$ years, accidents of this nature seemed to be of more frequent occurrence since this regulation was introduced than they were previously. Last year, 14 non-fatal accidents were caused by sparks from lamps falling upon blasting-powder, while for the preceding year there were 11 similar accidents. It was evident that by using safety-lamps these explosions of blasting-powder would become a thing of the past, but he suspected that rather than use safety-lamps the owners and workmen would prefer to abolish blasting-powder. Danger from a coal-dust explosion by shot-firing was only to be feared in comparatively few of the collieries in Scotland, and in the great majority of mines there was little reason to apprehend that an explosion of fire-damp of any extent could be caused by a blasting-powder shot. But as workmen could not take the precautions necessary for their own safety while using blasting-powder he considered that it would be a benefit if the order came into force, even in the mines which were practically free from gas and coal-dust.

Mr. J. A. LONGDEN (Stanton) wrote that Mr. Hall's paper was extremely interesting, and more especially so at this time because, as one of H.M. inspectors of mines, he no doubt put the case in the same way that it was put to the Secretary of State for the Home Department, and probably this statement caused the recent order as to the use of explosives to be issued. It was very satisfactory to find that Mr. Hall admitted that safety-explosives cost one-half more than blasting-powder, or 1d. per ton additional. He believed that one of the largest coal and iron companies in Lancashire had not paid more than 3 per cent. average dividend for the last 20 years, and their output was about 2,000,000 tons: 1d. per ton would make a difference to them of nearly £9,000 per annum, and in these days when good iron was being sent from the United States of America and competing with British iron upon favourable terms in our own markets, we could not afford to lose such sums as these. He was perfectly aware that H.M. inspectors of mines never considered cost, and he was also aware that all legislation tended to increase

cost. On the other hand, wherever colliery proprietors were satisfied that the adoption of other methods would decrease loss of life they were always willing to adopt suggestions, even although their enterprise might be an unprofitable one.

The object of the recent explosives order was an attempt on the part of H.M. inspectors of mines, who had really been the initiators, to prevent explosions of fire-damp or coal-dust, and Mr. Hall's paper gave elaborate figures comparing two of the mines inspection-districts. His experience had been entirely in the Midland counties, and he found that the output of coal in that district in 1895 was 20,000,000 tons against 14,000,000 in Northumberland; whilst, however, Northumberland showed 25 accidents by explosives, the Midland district only showed 9. Mr. Hall, in Appendix C, showed that 31 accidents with explosives occurred in the Northumberland district, and these accidents naturally divided themselves up as follows:—

No warning given to adjoining workmen	...	...	8 accidents.
Candles actually ignited the powder	...	...	6 „
Unskilful charging of holes	...	...	5 „
Men not far enough away when shot went off	...	10	„
Returned to a missed shot	...	...	2 „

And in each of these cases the accident might have been prevented if more care had been taken. In no case did the use of blasting-powder cause ignition of gas or dust, and it appeared to him (Mr. Longden) therefore that Mr. Hall's paper, so far as the Northumberland district was concerned, did not support his argument. The object of the Secretary of State's order was to prevent ignition of gas or coal-dust, and it did not in any way pretend to cause workmen to be more careful in going about their ordinary occupation. Even if the use of blasting-powder had fired gas it was not the fault of the blasting-powder, as the gas ought not to have been there.

As to using gunpowder to fire shots on roads, where fine dust existed, it was a mistake, and the first part of the Secretary of State's order, with some modification, should not be objected to; but the second part abolishing the use of blasting-powder altogether at the coal-face, quite irrespective of the varying conditions of the coal-seams, ought not to be allowed to pass without protest; there was no fear whatever of blasting-powder igniting coal-dust in the working-faces, as the dust was not sufficiently fine to be inflammable.

At the Stanton collieries, 180 shots are fired every day, 118 in coal and 62 in stone; $\frac{3}{4}$ lb. of blasting-powder is used for a shot in stone and

$\frac{1}{2}$ lb. for a shot in coal, and 12 ounces of blasting-powder is equal to $5\frac{1}{2}$ ounces of roburite. The blasting-powder shot requires a fuze which costs $\frac{1}{2}$ d., and the roburite-charge a detonator which costs 2d., therefore the costs of each shot are as follows:— $\frac{3}{4}$ lb. at 4d. per lb. + $\frac{1}{2}$ d. = $3\frac{1}{2}$ d. for each shot of blasting-powder in stone; $\frac{1}{2}$ lb. at 4d. per lb. + $\frac{1}{2}$ d. = $2\frac{1}{2}$ d. for each shot of blasting-powder in coal; and $5\frac{1}{2}$ ounces at 1s. per lb. + 2d. = 6d. for each shot of roburite in stone.

This statement showed that the relative costs per shot was $3\frac{1}{2}$ d. as against 6d., or 70 per cent. increase for stone-work where roburite was admittedly useful; but for coal the cost was $3\frac{1}{2}$ ounces at 1s. per lb. + 2d. = 5d. for each roburite-shot as against $2\frac{1}{2}$ d., or double the amount. If, therefore, the total cost of shot-firing was doubled in the Stanton pits, it would entail an increase of £700 per annum; but all the seams are worked by longwall, which method no doubt helps to get the coal, obviates shot-firing to a great extent, and thus reduces the number of shots compared with other methods. The "cutting" or "breaking-in" shot is not allowed, and the cutting has to be done by hand with the pick.

Mr. Hall's statement that the use of safety-explosives instead of blasting-powder had not increased the percentage of slack coal in the mines was very surprising. Supposing that $3\frac{1}{2}$ ounces of roburite would do as much work as $\frac{1}{2}$ lb. of blasting-powder in getting the coal, there still was a vast difference in the result; the roburite shattered a small cylinder, making dust round the hole and leaving the rest of the coal to be broken up by the pick, while blasting-powder, on the other hand, broke up the coal, comparatively without dust, into pieces suitable for loading. Mr. Hall had not taken this point into consideration, and perhaps he would explain whether there was not more work for the colliers in breaking up the coal when using roburite than there was when using blasting-powder. As a matter of fact, at a colliery in the Midland district, producing nearly 1,000,000 tons of coal per year, where the use of blasting-powder had been discontinued for coal-getting more than twelve months ago there had been an increase in slack of 2 per cent., and this increase of slack, on the average selling-price, was equal to a loss of 1d. per ton. Therefore, in a similar case to that of the large Lancashire firm previously referred to, this would be a further loss of £9,000 per annum, or a total loss to a similar colliery of £18,000 per annum; surely this could not be considered to be a matter of small consequence. There was no doubt that the Secretary of State's order was only the first instalment, and that another order would shortly be

promulgated necessitating the abolition of all naked lights. If there be one doctrine more objectionable than another it was that all men should have the same wage irrespective of age, occupation, or hours of work, and this order seemed to be rather on the same lines, viz., whether necessary or not, every colliery shall ultimately work with safety-lamps and discontinue using blasting-powder.

In the Midland inspection-district, the greatest number of fatal accidents was caused by falls, viz., 0·384 per 1,000 persons employed; Northumberland, with naked lights, showed 0·464; Yorkshire, with safety-lamps largely in use, 0·545; and West Lancashire, which was held up as a model, 0·967; surely this was an all-sufficient answer to the question regarding the advisability of using naked lights where it was safe to do so; and where naked lights were safe, blasting-powder could be safely used in the faces.

Prof. H. LOUIS (Newcastle-upon-Tyne) wrote that he welcomed Mr. Hall's paper as the first official defence, if he might call it so, of the Secretary of State's recent order, and as the first opportunity that mining engineers had had of seeing the arguments upon which this order must rely set forth in tangible form. As such, Mr. Hall's paper merited the most careful attention that could be bestowed upon it, and he would like to examine his arguments in their order. With regard to costs, he could not accept the results contained in Table I. in their entirety. At the outset, this table was unreliable, because it included blasting in both coal and stone, and there was little doubt in his mind that in the majority of cases a high-explosive was more suitable to stone-work than blasting-powder. He was quite aware that this was tantamount to saying that he considered blasting-powder more suitable than a high-explosive for a soft material like coal, and that was precisely his position. He could not agree with Mr. Hall's statement that "the statistics in each individual case prove almost identical facts," because he saw that his range of the comparative cost of blasting-powder and safety-explosives varied between 1 : 3·3 (No. 1 colliery) and 1 : 0·8 (No. 9 colliery). When one ratio was four times as great as the other the results could not be called identical, whilst striking an average was little if any better than guess work. He thought that a better plan would be to re-arrange the results contained in Mr. Hall's Table I. as follows :—

Number of Colliery.	Blasting-powder.			Safety-Explosives.				
	Tonnage.	Cost.			Tonnage.	Cost.		
		£	s.	d.		£	s.	d.
1	223,649	318	15	6	249,488	806	12	8
1	153,946	412	15	3	187,222	763	11	2
3	154,151	299	11	0	139,100	318	10	0
4	48,500	126	8	10	40,880	174	12	9
6	28,737	211	9	2	30,099	252	10	0
7	60,000	134	3	0	74,522	518	9	6
8	431,040	657	3	8	270,931	476	10	6
9	101,320	242	1	0	77,717	219	8	4
9	110,522	611	0	6	88,616	409	17	1
15	219,031	771	2	8	190,434	1,351	0	0
Totals ..	1,530,896	3,784	10	7	1,349,009	5,291	2	0

In this re-arranged table, he had only inserted those collieries in which the cost of blasting-powder and of a safety-explosive was given for the same mine, and had, on this ground, rejected Nos. 10, 11, 12, 13, 14 and 16 collieries. The figures for No. 2 colliery were open to doubt on Mr. Hall's own showing, and he did not think that No. 5 colliery could fairly be classed as a mine that used explosives in coal-getting; when the cost was as low as 0·12d. to the ton, no conclusions either way could be drawn from the results. From Table I. thus re-arranged, he found that the cost of powder per ton of coal was 0·59d., and that of the safety-explosive was 0·94d., or a difference of 0·85d. per ton, equal to an increase over blasting-powder of nearly 60 per cent. He ventured to think that this increment was more nearly correct than that given by Mr. Hall, and it was not one that could be disregarded as unimportant. Moreover, it would only be fair to add to this figure the cost of shot-firers' wages, which Mr. Hall had not done, as this item obviously increased the cost of coal-getting. He would like to see an explanation of the fact, that these collieries quoted in the table produced, as there shown, 200,000 tons less coal (or a reduction of 12 per cent. on the output) when high-explosives were used as compared to their output when using blasting-powder, a corresponding increase in the standing charges being thereby entailed.

As regards the proportion of round coal produced, we required more data than were given by Mr. Hall; the most notable fact was that in most cases quoted, the practice with blasting-powder of ten years ago was compared with that of last year with safety-explosives: did Mr. Hall wish members to believe that in his progressive and scientific district there had been no improvement made in coal-mining during ten years, except in the introduction of high explosives? The only collieries in

Table I. that he considered at all comparable were Nos. 2, 3, 4, and 6, and the average of these four showed 65·28 per cent. of round coal with blasting-powder and 63·41 per cent. with safety-explosives, a very different result from that obtained by Mr. Hall in what he could not but look upon as his somewhat indiscriminate use of statistics. He nevertheless held that it was in the highest degree unsafe to draw any definite conclusions from the very scanty data afforded, and would not like to have it inferred that he looked upon even the amended figures as a reliable guide to actual practice.

He could not agree that mine-owners had been lightly dealt with in the matter of legislative interference; on the contrary, he had endeavoured to show in a recent paper* that, during the period that legislation had been experimenting on the coal-trade of this country, Great Britain had come down rapidly from producing 75 per cent. of the world's coal to producing about 30 per cent., and that our chief rival—the United States of America—was enabled to undersell us, largely on account of the freedom from legislative trammels enjoyed by American coal-miners, whilst their death-rate compared very favourably with our own. Further legislation must inevitably tend to still further hamper the British coal-trade, and seemed likely to end in securing the safety of the coal-miners by closing down the coal-mines; it was a question whether the miner might not prefer the remote risk of explosion to the imminent danger of starvation.

He did not think that the method adopted by Mr. Hall in compiling Tables II. and III. was quite sound; it would be preferable to compare, not the number of persons killed and injured, but the number of individual accidents, whatever be the fatalities caused by them. The fact of the explosion being caused was the essential fact, the number of persons killed or injured was a fortuitous circumstance, with which the cause, at any rate, of the explosion, had no direct connexion. If Mr. Hall wished to show that safety-explosives were safer than blasting-powder in gaseous or dusty mines, he ought to have tabulated the number of explosions due to explosives in both districts side by side. He himself had attempted to do this, but had been stopped by the fact that no such data were available as regards the West Lancashire district, although they were for the Northumberland inspection district. Obviously, however antique and primitive the method of mining might be in the Northumberland district, the methods of recording mineral statistics in that district were far in advance of what they were in West Lancashire.

* *Iron and Coal Trades Review*, January 29th, 1897, page 178.

Upon the question of candles, he thought that Mr. Hall had proved too much. If blasting-powder was the cause of the excessive number of explosions in the Northumberland district, these could not be due to the use of candles; if candles were to be blamed, where did the proof of the greater safety of high explosives come in? It might be asked why in Table IV. the comparison between the Newcastle and West Lancashire districts had not been continued; it was hardly worth while, however, to raise this point, because it seemed difficult to believe that any one could seriously contend that a miner with a candle that lighted the roof had not a better chance of escaping falls than the man with a safety-lamp, the shield of which threw the roof into deep shadow. We may apply a method well known to logicians, and show that the logical outcome of such an argument would be the *reductio ad absurdum*, that the miner would be safer still in total darkness.

Mr. Hall's remarks upon the report for the Northumberland district for 1895, to the effect that "all the fire-damp explosions were caused by candles," afforded the best possible proof that blasting-powder was not dangerous in these particular mines. He (Prof. Louis) had in another paper* collected some statistics which showed that only about 1 shot in 1,000,000, taking the average of the United Kingdom, caused an explosion of fire-damp or dust, whether fatal or otherwise, and he ventured to think that so high a ratio of safety could hardly be improved upon by legislation, and submitted that Mr. Hall had not made out a sufficiently strong *prima facie* case for safety-explosives to show that their general adoption throughout the Northumberland district was advisable. While anxious to do all in his power to advance scientific mining, he could not admit that scientific mining consists in indiscriminately applying absolutely identical methods of working to districts and seams with essentially different characteristics.

Mr. J. S. MARTIN (H.M. Inspector of Mines, Bristol) wrote that from an estimate which he had made for the South Western inspection district, based upon a return of the number of shots fired, he calculated, making an extravagant allowance for the number of shots not returned, taking the price of permitted explosives at double that of powder and the respective strengths at $\frac{1}{2}$ instead of $\frac{2}{3}$, which was found most advantageous with one of them (carbonite), also the cost of detonators, etc., at 1d. per shot, and the appointment of a shot-man at 4s. 6d. a day for every 15 shots, that the additional cost entailed by the Secretary of

* *Colliery Manager*, 1897, page 154.

State's order for the output of coal, 11,844,999 tons, in his district would only amount to 0·175d. per ton, while he believed that the actual cost would be covered by 0·10d. He had received statements from the managers of two thin coal-seam mines in his district, in which one stated that the cost of explosives per ton of coal raised during a half-year, while blasting-powder was being used, was 0·32d. per ton, and that for the corresponding half-year when one of the permitted explosives was in use was 0·88d. per ton, the output and the conditions being practically similar; and the other, that for the half-year with blasting-powder, the cost for explosives was 0·39d. per ton, and the corresponding half-year with a permitted explosive the cost was 0·56d. per ton, the output and conditions being practically the same. The explosives in both these cases were found by the owners for all the work in the mine, so that the quantities are accurately known, and therefore the comparisons, extending in each case over the whole half-year, were satisfactory.

He had had the results of experiments made at his request by colliery managers communicated to him, carbonite being the explosive used, and the charges being as 2 : 5 as compared with the amount of blasting-powder that would have been used in the ordinary way: the results, *i.e.*, the quantity of coal got down, and the size, were eminently satisfactory.

The quantity of the permitted explosives at present in use in his district, he estimated from a return received, to be two-fifths of the total explosives used. These explosives had been introduced gradually during the last three or four years at his request, and without creating any friction with the workmen, who, after having gained experience with their use and comparative strengths, appeared to like them.

He appended Table I. showing for the last ten years the number of persons killed and injured by the use of explosives, as well as of the

TABLE I.

			Explosives.				No. of Persons Employed Underground.
			Killed.		Injured.		
1887	...	...	—	...	21	...	30,686
1888	...	...	1	...	16	...	31,012
1889	...	...	1	...	12	...	32,651
1890	...	...	3	...	14	...	35,226
1891	...	...	—	...	13	...	37,397
1892	...	...	—	...	9	...	36,715
1893	...	...	1	...	9	...	37,079
1894	...	...	—	...	7	...	38,038
1895	...	...	2	...	6	...	38,022
1896	...	...	2	...	7	...	38,385

number of persons employed underground in his district, from which it will be seen that a very considerable reduction had taken place since safety-explosives had been introduced.

He referred to the fact that of the persons killed and injured in his district by explosions of fire-damp or coal-dust during the last five years, 11 out of 12 of the deaths resulted from the use of blasting-powder (9 in mines, Camerton and Timsbury, in which fire-damp had not previously existed), and of the persons injured, 17 out of 20 were the result of using naked lights.

Table II. showed the enormous improvement and increase in the number of persons employed for each death from falls of roof and side which had taken place in his district since 1873, co-existing with the increased use of safety-lamps.

TABLE II.—SHOWING THE QUANTITY OF MINERAL RAISED, NUMBER OF PERSONS EMPLOYED UNDERGROUND, NUMBER OF DEATHS FROM FALLS OF ROOF AND SIDE, NUMBER OF SAFETY-LAMPS IN USE, THE QUANTITY OF MINERAL RAISED, AND NUMBER OF PERSONS EMPLOYED UNDERGROUND FOR EACH DEATH FROM FALLS OF ROOF AND SIDE, FROM 1874 TO 1896 INCLUSIVE, IN THAT PART OF THE SOUTH WALES COAL-FIELD INCLUDED IN THE SOUTH WESTERN MINES INSPECTION DISTRICT (MONMOUTHSHIRE AND PARTS OF BRECON AND GLAMORGAN).

Year.	Mineral Raised.	Persons Employed Underground.	Deaths from Falls of Roof and Side.	No. of Safety-lamps in Use.	Mineral Raised for each Death from Falls of Roof and Side.	Number of Persons Employed Underground for each Death from Falls of Roof and Side.
	Tons.				Tons.	
1874	5,398,630	17,779	28	—	192,808	635
1875	4,510,110	17,966	21	1,755	214,767	855
1876	5,569,623	17,845	23	1,804	242,157	776
1877	5,432,391	17,489	23	1,814	236,191	760
1878	5,495,240	17,066	41	2,194	134,030	416
1879	5,519,980	15,964	39	2,037	141,538	409
1880	6,033,828	15,996	25	2,949	241,353	640
1881	6,369,136	16,607	33	2,971	193,004	503
1882	6,734,120	17,363	28	3,638	240,504	620
1883	7,431,263	18,964	26	3,541	285,818	729
1884	7,490,976	19,923	26	3,983	288,114	766
1885	7,256,767	20,441	27	5,047	288,769	757
1886	7,149,722	19,171	22	5,283	324,988	908
1887	7,597,806	20,669	30	5,937	253,260	689
1888	7,724,448	21,108	21	6,585	367,831	1,005
1889	7,727,300	22,469	24	7,455	321,971	936
1890	7,873,046	24,330	22	9,400	357,866	1,106
1891	8,065,049	26,203	22	11,868	366,593	1,191
1892	8,107,334	25,828	20	12,282	405,367	1,291
1893	8,008,811	26,600	23	15,707	348,209	1,157
1894	9,193,683	27,730	21	18,326	437,794	1,320
1895	8,782,697	27,847	30	18,516	292,756	928
1896	9,840,464	28,325	27	19,544	364,462	1,049

The figures recorded in Table II. related to that portion of his district which was included in the South Wales coal-field, and in which fire-damp was largely met with. The comparisons were all the more important and more favourable when it was borne in mind that 100 per cent. more coal was worked from the fiery steam coal-seams now, and at very much greater depths than formerly, the circumstances being, according to the argument of naked light supporters, entirely against any improvement.

Mr. J. G. WEEKS (Bedlington) wrote that Mr. Hall, one of H.M. inspectors of mines, had written a paper purporting to deal with "The Cost and Efficiency of Safety-explosives as compared with Gunpowder." Seeing that the recent order of the Secretary of State, promulgated most probably after consultation with himself along with the other inspectors, was under appeal by petitions from both the employers and employed in the counties of Northumberland and Durham, the paper in question was one that should, in his opinion, not have been originated at this juncture.

The paper dealt with blasting-powder and safety-explosives, yet in Table I., No. 7 colliery, gelignite was named as the explosive in use, and no doubt formed an ingredient in the so-called deductions. Gelignite was not a safety-explosive and should be eliminated.

The figures of 0·61d. per ton for blasting-powder and 0·92d. per ton for safety-explosives may be the representative costs per ton of the respective explosives in the evidently soft coal-seams of Lancashire, judging from the small percentage of round coal shown in Table I., but such costs did not represent those of other districts where the seams were of a different average height and of a different degree of hardness.

It was obvious that the cost per ton would vary with the thickness of the seam mined and with the number of shots and the quantity of explosive used to bring down the coal, with the hardness of the coal, the readiness or otherwise with which it separated from the roof or floor of the mine, or the various beds of stone or band with which the seam of coal wrought may be interstratified. The cost in steam-coal collieries of safety-explosives was very much in excess of Mr. Hall's figures.

With regard to stone-work, it had not been found in his practice that safety-explosives had an advantage of at least 25 per cent. over blasting-powder; however true this may be of Lancashire with its rocks and metals (in which last measures, we are told in the paper, there was no difference between blasting-powder and safety-explosives) it was not

found to be so in the strata met with in the steam-coal collieries of Northumberland, and the cost of safety-explosives in stone-work (bellite) may safely be put down at least as double that of blasting-powder.

There was, however, beyond this item of the question of cost—in itself an item, as he was well aware, of no account with certain theorists—the not unimportant consideration of what physical results, the firing of high or safety-explosives had, upon the overlying and surrounding substances other than that which was immediately mined and removed. Effects that did not immediately show themselves, but which followed these results, he suggested would be found in the casualties that resulted from falls of roof and sides. Unfortunately Mr. Hall had omitted to give in tabular form these figures for his district, but had substituted a table relating to the Northumberland and Durham inspection-districts, to attempt the proving of something that had nothing to do with safety-explosives. It was perhaps too late to ask him to supply it now, and possibly were it produced, the result would show that the nemesis of the safety-explosives was a deity that required the loss of five or six times the number of lives which the writer of the paper endeavoured to show was required from those carelessly handling blasting-powder.

Mr. Hall, with the zeal of an advocate, introduced a tabular statement as to deaths from explosions of gas by candles—a matter totally foreign to his subject, and he did not therefore further allude to it, except as to its being extraneous to the matter under notice.

He objected to Mr. Hall's very sweeping remarks, where he stated that in the steam-coal collieries none of these safeguards have been introduced, as it is an exaggerated statement. He had used bellite since 1892 at the pits of the Bedlington Coal Co., Ltd., one of the largest steam-coal collieries in Northumberland, and safety-lamps since 1872, and of his own knowledge knew of lamps being in use in 1859, and probably long before. If the rest of Mr. Hall's so-called facts were as recklessly extravagant, he was afraid that the result would be not to remove misconceptions, but to create them.

Mr. T. R. ELLIS (Wigan) wrote that there was a general consensus of opinion amongst coal-owners that alterations should be made in the explosives order in certain matters of detail, but Mr. Hall's paper and his figures gave what seemed to him to be an unanswerable support to the view which he thought was generally held in Lancashire, that the order (in whatever form it should be ultimately approved) should apply to every district alike.

Mr. J. B. SIMPSON (Newcastle-upon-Tyne) wrote that Mr. Hall in his estimates as to the cost per ton of coal, of gunpowder and other explosives, did not add anything for the shot-firer, which, in many cases, would be a considerable additional expense.

It seemed to him that, generally, Mr. Hall's comparison was not a fair one, and that he had not arrayed a sufficient number of facts in each district, such as the number of accidents, as well as the deaths, the hardness of the coal and stone, the number of shots fired, and many other particulars, to enable a fair comparison to be formed, and he could not therefore accept his conclusions as being correct.

He noticed that Mr. Hall had not given a detailed account of the accidents from blasting-powder, etc., in West Lancashire as he had done in Table I. for Northumberland, and, therefore, on this point one could not make a comparison. He also thought that the author in endeavouring to compare Northumberland with West Lancashire in Tables II. and III., should have continued the comparison as to the falls of roof, and Table IV. should have been differently constructed, but he no doubt foresaw the result and went off at a tangent, comparing Northumberland with Durham, and made a haphazard statement that in Durham safety-lamps were generally used, and in Northumberland candles largely used. He objected to this statement, as it was not accompanied by statistics to prove it, and believed that the truth was the other way, but, whether or not, he neglected the fact, which he should have known, that the Northumberland statistics include a large proportion of Durham, so that this comparison was worthless.

As Mr. Hall had not compared West Lancashire with Northumberland as to falls of roof, he would do it for him, and make a revised Table IV. as follows :—

Years.	Northumberland Mines Inspection-District.		West Lancashire Mines Inspection-District.	
	Deaths.	Persons Employed Underground.	Deaths.	Persons Employed Underground.
1891	32	53,140	60	44,472
1892	37	54,397	40	46,044
1893	47	54,325	41	46,444
1894	37	56,726	43	47,108
1895	26	56,076	45	46,587
Totals and averages...	179	54,932	229	46,131

The preceding table showed the net result for the five years to be, that in Northumberland there was 1 person in 1,534 killed by falls of stone,

and in West Lancashire 1 in 1,007, showing Northumberland, in this respect, to be 53 per cent. safer.

He thought that Mr. Hall, before taking upon himself the position of an umpire, should, in coming to a decision, have evidence of all material facts of the cases, as it seemed to him a very dangerous thing to compare one district with another, without knowing fully the varying conditions of each; and especially before charging any district with want of skill, and making other disparaging statements against it.

He strongly objected to his using such an expression as "obstinate adherence to antique methods of mining" being applied to Northumberland; and further, he did not think that one of H.M. inspectors of mines was justified in using it.

He would carry Mr. Hall a little further in his comparison of Northumberland with West Lancashire. Taking all the accidents for the past five years, the total loss of life underground was, in Northumberland, 1 person killed for 785 employed, and in West Lancashire 1 in 616; and during the year 1895, he found that for 1 death in Northumberland 255,900 tons of coal was worked, and in West Lancashire 1 death for 142,610 tons worked, or in Northumberland nearly double the quantity of tons per fatal accident: so that, after all, its "antique method of mining" was not the most dangerous in the country. He did not agree with Mr. Hall that he had endeavoured to remove misconception; but, on the contrary, he had endeavoured to bolster up his theories by giving unfair comparisons and withholding material statistics.

In Northumberland and Durham, we were as much alive to the safety of mining as Mr. Hall could be; and we were quite as able to decide, when proper facts were placed before us, as to whether blasting-powder or so-called safety-explosives were the better. Mr. Hall's paper, he thought, should have comprised only the statistics that he had obtained, and should have omitted his haphazard remarks and comparisons, which appeared to him worse than mischievous.

Messrs. T. E. FORSTER and H. AYTON (Newcastle-upon-Tyne) wrote that at the outset, Mr. Hall spoke of the permitted explosives in the Explosives in Coal-mines Order, 1896, as being the most "suitable and reliable." As to the reliability of all of them, there would appear to be some doubt, since certain of these explosives, after undergoing a series of exhaustive tests at Hebburn, certainly did not show that they could be depended on with anything like certainty.

They had grave doubts as to the value of the figures given in Mr. Hall's paper. Averages taken in the way in which Mr. Hall had taken

them were very apt to be deceptive, and a comparison between results obtained in some cases as far back as 1882 to 1888, and those of last year were unreliable. There were a great many other facts and conditions which would have to be carefully enquired into, before anyone would be justified in drawing such a hard-and-fast line as to the cost of safety-explosives as compared with blasting-powder.

Concerning the percentage of round coal obtained by safety-explosives, here again they could not consider the results as by any means a fair average. There were only four of the collieries which recorded the results of consecutive or nearly consecutive years, putting aside the case of gelnite, which was neither blasting-powder nor a safety-explosive. These four instances were, they thought, quite sufficient to prove that Mr. Hall's figures were untrustworthy.

The mischief caused by high explosives was not, however, always discoverable on the screens, especially in the case of coals disposed of by shipment, which was very largely the case in the two northern counties. It was, they believed, a fact that the disintegration during the voyage was found to be much greater after the use of safety-explosives, and this in itself was undoubtedly a very serious question where foreign competition was directly encountered.

As to the 25 per cent. of economy in cost of safety-explosives when applied to stone-work, Mr. Hall appeared to be satisfied by merely making the bare assertion without appending any figures to support it, except in one case which he mentioned. This statement was contrary to their experience.

As regards the remainder of the paper, Mr. Hall wandered from his subject to discuss various points which were unconnected with the matter he had in hand, with the object apparently of proving that Northumberland steam-coal collieries were serious defaulters. In order to do so, he made comparisons, in the first instance, between the West Lancashire and the Northumberland mines inspection-districts, which showed at once that he had no acquaintance with the latter. In the case of falls of roof and side, he compared the Northumberland mines inspection-district with the Durham mines inspection-district, leaving West Lancashire in the background. The reason for this was only too evident to anyone who would take the trouble to look up the statistics for West Lancashire.

There was nothing to show where Mr. Hall had acquired his information as to no safeguards, such as so-called safety-explosives and safety-lamps, being used in Northumberland steam-coal collieries; but they

could assure him that such was not the case, since more than one colliery had for some time now used a safety-explosive mentioned in the order of the Secretary of State, and safety-lamps were by no means an unknown commodity in those mines "specially favoured by nature." That there appeared to be a "serious misconception" with regard to Northumberland they readily agreed, considering that the Explosives in Coal-mines Order was issued with a view to the prevention of accidents from explosions of gas and coal-dust; but to infer that by using safety-explosives the accidents which Mr. Hall enumerated in Appendix C would have been prevented was undoubtedly a question open to dispute.

So far as "haphazard statements" were concerned, they quite agreed with Mr. Hall, and for this reason they thought it would have been preferable and would have enhanced the value of his paper had Mr. Hall made himself better acquainted with this district before writing upon it.

Mr. W. O. WOOD (Sunderland) wrote that Mr. Hall's paper was a striking exemplification of the axiom that figures and statistics could be made to prove anything, and the danger and misleading character of statements containing half-truths. Having been amongst the pioneers in the use of safety-explosives in the county of Durham he might claim to be as strong an advocate of their use, where the conditions render them necessary, as the writer of the paper.

He failed to see the startling character of the statistics contained in Table II., as he had looked over the details of the Northumberland accidents in 1895, and unless the other years showed different results, a very poor case was made out against blasting-powder. The 7 fatal cases and 29 injuries were reduced at once to 6 and 28, as one of each was with gelignite and not with blasting-powder. Of these, 5 fatal cases and 17 cases of injuries might, in his opinion, have occurred with any other explosive; so that the number dwindled to 1 fatal case and 11 cases of injuries. In addition, he was of opinion that, to make a fair and reliable comparison, the quantity of blasting-powder used or the estimated number of shots fired in each inspection district should have been set out.

He regretted his inability to confirm Mr. Hall's statement with regard to the superior efficiency of safety-explosives for ordinary stonework. In his experience, instead of being 25 per cent. better, safety-explosives were no better, and certainly much more expensive.

As regards the use of safety-lamps, he would by all means substitute them for candles where found necessary, but he could not for a moment

suppose that Mr. Hall seriously suggested that an ordinary safety-lamp gave as much light as a candle ; at all events he had not yet made the acquaintance of that lamp, unless it be an electric one.

He thought that Table IV., containing a comparison between the Durham and Northumberland mines inspection-districts, was quite misleading, as a large proportion of the Durham pits used candles, whereas the table treated all of them as being users of lamps. Without the numbers using the respective systems being detailed, Table IV. was quite useless, as the mines using candles in Durham were as safe as open quarries. The application of the Secretary of State's order to such mines was oppressive and absolutely unnecessary, and no one knew or ought to know their characteristics better than Mr. Hall. The Durham colliery of which Mr. Hall was in charge during his career as a mining engineer was (and is) of this character, and so were all the mines in the very large district in which it was situated. He could not conceive that Mr. Hall really believed in the necessity of the application of the Secretary of State's order to such mines, or that it was not a serious and unnecessary burden on the industry.

Mr. G. E. J. McMURTRIE (Cinderford) wrote that Mr. Hall's paper was probably the most important communication on the comparative costs of gunpowder and the permitted explosives that had yet appeared, embracing as it did the results of twenty firms who drew 5,000,000 tons of coal per year. He had made a few comparative experiments with carbonite and gunpowder which showed that the cost of the permitted explosives was double that of gunpowder in working coal, nearly double that of gunpowder in shale, and practically the same in rock. Mr. Hall's figures for coal showed that the cost of permitted explosives was half as much again as gunpowder, while for stone-work he claimed that the permitted explosives were more economical. An extended use of carbonite would no doubt also reduce in his (Mr. McMurtrie's) case the cost of the explosives per ton, possibly as low as Mr. Hall's figures. But in his case, as the district was non-fiery, the additional cost of shot-firers must be added. In limited experiments it was impossible to obtain any reliable results as to the relative proportions of large and small coal, but in some of the shots no more breakage resulted with carbonite than gunpowder would have produced.

The closer sizing of coal by mechanical screens must add to the proportion of large coal in spite of the better screening which ensured less slack being left in the better qualities, and thus the alteration in the

last few years in screening must prevent the obtaining of reliable relative results as to the effect of the explosives on the size of coal produced. In addition to this, the coal worked at most collieries varied greatly in hardness from time to time, and this variation precluded the obtaining of exact figures for the purposes of comparison.

Many mine-owners and colliery managers could not accept Mr. Hall's statement that they had not been severely dealt with by legislation. Many persons stated that legislation had entailed an increased cost of production of at least 1s. per ton, and even if this figure be deemed excessive there was no doubt that considerably increased cost had ensued.

The comparative figures given as to the killed and injured by explosives in Northumberland and West Lancashire were very striking, and clearly showed that additional safety was obtained by the use of the permitted explosives. It would, however, be of general interest to know how much of this improvement was due to firing by electricity, which, strangely enough, had not been made compulsory by the Secretary of State's order.

The results contained in Tables II., III., and IV. showed that the additional safeguards obtained from recent writings and experiments and the resultant legislation therefrom had materially reduced the loss of life due to the causes considered in Mr. Hall's paper, and should urge mining engineers to renewed efforts to secure further efficiency.

Mr. H. HALL, replying to the discussion, thanked the members for the courteous way in which they had received his paper. The President had asked whether in estimating the cost he had taken into consideration the regulation that the workmen had to be withdrawn when certain shots were fired. The cost of that precaution—whatever it might be—was not included in the cost which he had put before the members. The workmen only had to be withdrawn in the case of shots being fired on main roads. He did not think that inspectors would strain "main haulage" into "stone drifts." The President also drew attention to the fact that in some collieries there would be a larger number of shots fired than in others. No doubt that would be so, but he had taken a large number of collieries, many working hard coal-seams, and firing a great many shots, and the result was computed from those collieries. The steam coal-seams of Northumberland might be harder than some of the Lancashire seams and take more blasting, but he did not think that the difference would be very great. In the case of a colliery (No. 6, North Wales) working under the sea, where none of the pillars were taken out, and the explosive cost was entirely for straight work in the same seam,

one side of a fault was worked with blasting-powder, and the other with electronite. The workmen riddled the coal underground and sent up the round and slack coal separately, so that a very fair comparison could be made. The difference of the cost of the explosives—1·76d. for blasting-powder, and 2·01d. for electronite—was $\frac{1}{4}$ d. per ton, and the percentage of round coal showed a difference of 2 per cent. in favour of blasting-powder.

He had been asked why he had not compared Northumberland with West Lancashire as regarded falls of roof. He compared Northumberland with Durham because they were most like in natural circumstances. In Lancashire, the roofs of the mines were very much worse than in Northumberland, in consequence of the Lancashire mines being situated very much higher up in the Coal-measures. He knew that West Lancashire was dreadfully bad in falls of roof, due to bad roofs and workmen timbering their own places. Statistics always proved that where any matter had been left to the workmen there had been no advance in the past 100 years, but in any matter left to the owners there had been a remarkable progress.

Mr. Steavenson had pointed out that all recent explosions had been in unexpected places; in fact, the four last explosions had happened in coal-mines in which it had been held to be impossible that such accidents could happen. Brancepeth, Micklefield, and others showed that no reliance could be placed on the opinion that a mine was safe.

Mr. Dickinson had pointed out that many accidents in his list were due to careless handling of explosives. That was an important matter in comparing the two classes of explosives. In the use of safety-explosives, bad handling could scarcely cause an explosion, as they would not explode unless detonated, they would not take fire, and were much safer to handle in the mine. It was the fashion to say that mining legislation had cost 1s. per ton. Mr. Dickinson suggested that it had cost 6d. per ton, but he challenged the members to show that legislation had enhanced the cost of working by 1d. per ton.

He had an impression that the Secretary of State's order did not apply to ironstone-mines.

The question of fumes had, in his opinion, died out where safety-explosives were used.

The cost that he quoted included stone-work in some cases, but it did not seem to increase the cost.

The detonator named in the order was that fixed by the manufacturer'sive.

He had taken nearly 20 firms, raising 5,000,000 or 6,000,000 tons, and the figures sent to him by the owners, derived from actual working over a long period, were more satisfactory and reliable than any experiments could be.

The only suggestion that he would make with reference to the Explosives in Coal-mines Order was that it might be modified. The words "main haulage-road" implied some main road where the haulage served a main district, but to extend it to working-places and stone-drifts was carrying the enactment too far, and making greater difficulties for the workers than could be compensated by any advantage in the way of safety. The same opinion applied to the definition, not given in the Explosives in Coal-mines Order, of a main intake—a main intake seemed to refer to an intake of fresh air serving a main district of the mine. Some of these modifications might be made in the order without any loss in the direction of safety.

Mr. Head seemed to estimate the worth of getting quit of colliery explosions at 1d. per ton, and spoke of foreign competition. At the present moment, however, more coal was being raised and used in Great Britain than had ever been worked previously, and the members would agree that it was being sold at a sufficiently low price.

He (Mr. Hall) thought that some reply was due to the members who had contributed in writing their observations on his paper, but perhaps this reply would preferably be in the form of a general statement rather than an attempt to answer each writer separately.

He wished in the first place to remind the members that the statistics given in the paper could not be said to be his statistics. Those contained in Table I. were supplied by the managers of the several collieries applied to for information and were given as received without a figure being altered, and those in Tables II. and III. were a mere recapitulation of the figures found in the Annual Reports of H.M. Inspectors of Mines.

There was no selection of firms, beyond the fact that the larger firms were asked as being most likely to have the information available, and had the figures proved to be precisely the reverse of what they were, that fact would not have deterred him from submitting them to the members. He was as much surprised at the result of the comparisons as to safety (contained in Tables II. and III.) as any of the members could be, and he quite agreed with the several gentlemen who pointed out imperfections, especially in Table I., and also that the statistics in that table would have been more conclusive if it had been practicable to include a wider area, but that under the circumstances was not possible.

As it happened, West Lancashire had had a longer and more extensive experience of safety-explosives than any other district, and it was therefore natural that West Lancashire should be selected as being most likely to afford the best information as to the cost and effect of changing from blasting-powder to safety-explosives. Northumberland had on the contrary identified itself as the upholder of the system of blasting-powder; hence the comparison of the two districts.

He had endeavoured to allow the statistics to speak for themselves as far as possible, and he only drew such conclusions as were palpable and unavoidable. Some of the writers complained of the conclusions drawn as being somewhat unfair, but he thought that if they examined the statistics carefully and impartially they could hardly justify that view. He noticed that several of the writers, notably Prof. Louis, manipulated the statistics in a different way from the author, with the result that his conclusions and the author's were almost identical; and whenever the writers quoted examples of their own experience, their results did not differ materially from those given in his paper.

He would be glad if some member who had a liking for statistics would take in hand Tables II. and III. and hunt up all the details of each accident in the lists; by doing this he would obtain even more decisive evidence in condemnation of blasting-powder and candles than was shown by the tables in their present form.

It was important to remember that the Northumberland inspection-district produced, as pointed out by Mr. Merivale, 30 per cent. more coal than Lancashire, with a similar number of hands underground, this implied that the coal was more easily worked in Northumberland, or it might be that the seams being thicker there, each shot brought down a large quantity of coal, and thus ton for ton less explosive was needed in Northumberland. (Mr. Merivale's inference was the reverse of this.)

It was, he thought, likely that there were both in Durham and Northumberland a considerable number of collieries of the class suggested by Mr. W. O. Wood, where fire-damp was never found, and these in consequence would escape the provision as to electric firing, and thus be spared a material part of the cost of the change.

Should the quantity of small coal be excessive, a remedy could be found by firing all coal-shots after the colliers had left, as under this system the men holed their coal 12 or 18 inches deeper, and thus more round coal was obtained.

It may be taken for granted that even in the absence of any explosives order the question of miners firing their own shots would have been dealt with in new special rules.

It would hardly be of interest to the members to attempt to deal with the various opinions which had been expressed, although they were by no means unanswerable, because mere expressions of opinion unbacked by facts were really not very convincing, though as coming from men of experience they must be treated with respect.

He was sorry if the words "antique" and "primitive" used in the paper had given real offence to anyone, but those words were certainly descriptive of how such things as candles, squibs, and straws in coal-mines appealed to him. He must confess that he could not understand the mental attitude of mining engineers who adhered to them, in the face of such accidents as those recently occurring at Brancepeth and Micklefield collieries.

The PRESIDENT, in moving a vote of thanks to Mr. Hall for his interesting paper, said that he was glad to hear Mr. Hall state that there was a possibility of getting the application of the order modified. Blasting-powder was used in about half of the mines of the Northumberland inspection-district. If the Secretary of State would revise the order and alter its provisions so that explosives could be more freely used, he would meet the views of the coal trade generally.

The vote of thanks was accorded by acclamation.

The following paper by Mr. J. Coquillion on the "Determination of Fire-damp in French Collieries" was taken as read :—

DETERMINATION OF FIRE-DAMP IN FRENCH COLLIERIES.

By J. COQUILLION.

History.—In 1875, after the explosion at the Jabin Pit, Saint-Etienne, attention was turned to the fire-damp question in France. The National Assembly voted the sum of £2,000 (50,000 francs) for making experiments and conducting investigations as to the possibility of lessening the dangers incurred by miners; and a commission was appointed. Mr. Grüner, vice-president of the Council-General of Mines, was of opinion that, in the then state of science, air alone could not be freed from fire-damp, and that consequently a more active ventilation was required which, penetrating into the working-places, might drive out the dangerous gases. In order to keep a check upon the ventilation, it was necessary to possess sufficiently correct fire-damp indicators, and also apparatus for making quantitative analyses, which should permit of controlling and checking the composition of the air in the working-places. When making his first investigations in connexion with the analysis of combustible gases, the author placed himself in communication with Mr. Grüner, who attached considerable importance to the improvements introduced into the apparatus used for this purpose.

Unfortunately however death soon overtook Mr. Grüner; and the commission which had been appointed, pursuing other views, limited its labours during twelve years to making laboratory experiments which led to no practical result. Inasmuch however, as explosions continued to occur, public opinion was roused; and a fresh commission was appointed, which followed up the ideas of Mr. Grüner, while the methods of working were modified. In some pits, two fans were erected instead of one; and a systematic watch on fire-damp was begun. No attempt was made however to found, as in Germany, experimental stations for making observations on fire-damp and ventilation, placed in charge of practical chemists; and at Saint-Etienne, workmen, trained for the purpose, made the determinations or the observations. Moreover, the whole reform is contained in the special regulations issued about a year ago, of which the following are the main provisions :—

The fire-damp content in the return airways shall be taken daily in mines undoubtedly subject to fire-damp, and at least once a week in those but slightly so subject, the observations being recorded in a book on the day that they are made. Every fiery mine must be provided with two fire-damp indicators and an apparatus for making quantitative analyses of the air. The indicators must record a content of $\frac{1}{2}$ per cent. of the dangerous gas; and their use should not involve greater danger than what may result from the use of safety-lamps of the types adopted.

The object of this paper is not to deal with the working of coal or the ventilation of collieries, but simply to describe the apparatus devised by the author for determining the percentage of fire-damp, viz. :—

(1) Apparatus for return airways, giving the fire-damp content correct to within 0·01 per cent.

(2) Laboratory apparatus, working with water, permitting an approximation of 0·10 per cent., while it also gives the carbonic acid and oxygen contents.

(3) Combustion over mercury, permitting an approximation of 0·20 per cent.; and

(4) The portable indicator, that may be used in the mine, and practically gives results correct to within $\frac{1}{4}$ per cent.

1.—FIRE-DAMP INDICATOR GIVING INDICATIONS CORRECT TO 0·01 PER CENT.

Referring to Fig. 1 (Plate I.), the bell-glass *G*, of about 12 cubic inches (200 cubic centimetres) capacity, is closed at the bottom by an indiarubber plug or cover with four holes, of which two receive the brass terminals of a battery or any other source of electricity, holding between them, by means of binding-screws, a coil or spiral of platinum wire *P*, inside and at the bottom of the bell-glass. The remaining holes receive two glass tubes, one of which, *A*, rising to the top of the bell-glass, is bent horizontally below the indiarubber plug, and is connected by means of a T-shaped tube both with the bell-jar *V*, to which is transferred the gas to be analysed, and with the bent tube *N*, that dips into the vessel containing water in which *V* is also immersed. The connexions are made with pieces of indiarubber tubing; and communication is made or shut off by stopcocks or clips. The graduated tube *B* does not rise higher than about $\frac{3}{8}$ inch (2 to 3 millimetres) above the indiarubber plug, so as to ensure its being sealed with water; but it is continued downwards for about 4 inches (100 millimetres), terminating in a bulb, so as to allow the gas to expand freely, and is connected by an indiarubber tube with the lower portion of the receiver *R*, which may be raised or lowered as desired.

The inside diameter of the graduated tube *B*, when the quantity of gas to be dealt with is slight, is about 0.06 inch (1 to 2 millimetres), so that a cubic centimetre may be divided into 20 or 25 parts; but in the case of a mixture containing a larger proportion of methane it must have a larger diameter. The glass cylinder *M*, permitting of water circulation, surrounds the bell-glass *G*, and may either stop short at the level of the india-rubber plug, being itself closed by a cork cover, as shown in Fig. 1, or it may be continued downwards so that the graduated tube may be surrounded by water, in which case the terminals and the exit-tube must be continued so as to pass through the cork cover. The whole arrangement is held in place, at a suitable height, by the stand *D*.

Preparing the Apparatus for Use.—The vessel *C* and bell-jar *V* must be filled with water of practically the same temperature as that circulating through the cylinder *M*. The movable flask *F*, also filled with water of the same temperature, is raised, so as to allow the water to flow into the graduated tube *B* and thus into the vessel *G*, while the air escapes through the end *H* of the tube *N*. The air will soon be driven off, and the whole arrangement filled with water, if care has been taken to regulate the current of water circulating through the cylinder *M*. The cocks must then be closed—or the clips tightened, as the case may be—and the flask kept at rest in its position. Unless the gas to be analysed has already been introduced into the bell-jar *V*, this must now be done; and there only remains to transfer it to the vessel *G*.

Working of the Apparatus.—If the bell-jar *V* be placed in communication with the vessel *G* by opening the cock *R*, and if the flask *F* be lowered, the gas contained in *V* will rise, drawing along the water in the tubes, and will pass into the vessel *G*. When it has practically attained the level of the platinum spiral, the cock *R* is closed, and the cock *R'* opened, while at the same time the flask *F* is lowered. The water will rise, driving before it, into the vessel *G*, the gas left behind that might escape being burnt; and it will soon reach the top of the inlet-tube. Both stopcocks must now be closed, and the flask allowed to remain in its then position, when the water will stop at a certain level. The operator must wait until the level is stationary, showing that the volume is constant; and in this connexion it may be observed that there are water-seals throughout, so that escape of gas or entrance of air is impossible. The length of time necessary for the water-level to become stationary, and consequently the volume constant, depends upon the difference between the temperature of the water and that of the gas introduced. If the flask be placed above the level of the water in the tube, the

observation will be made under pressure ; and, if it be placed below, the pressure will be less than that of the atmosphere.

Making an Observation.—When the level has become constant, as ascertained by observing the division on the graduated tube *B*, at which the water has stopped, or by a small index sliding along the tube, the battery or other source of electricity is connected, and the current made to pass through the platinum spiral, which is thus rendered incandescent. The observer must first ascertain, however, that the wire is not liable to melt ; but, if this should happen, the wire may easily be renewed. The experiment may last 20 seconds, which is generally sufficient ; but it is advisable to pass the current twice running through the platinum wire, with from 3 to 4 seconds interval between, in order to make sure of burning all the gas. The operator must wait until the apparatus cools down ; and the gas will take some little time to return to its point of departure. In an experiment made with pure air, from 10 to 12 minutes are required for the water-level to return to the same point ; but at the end of this period, when the mixture contains one 10,000th part of methane, it will have exceeded the original level by 0·01 inch.

To test the apparatus with so small a proportion of this gas, the author introduces 0·61 cubic inch (10 cubic centimetres) of methane into a flask full of air placed over water, and having a capacity of 60 cubic inches (990 cubic centimetres), thus forming a 10 per cent. mixture. From the latter he takes the same quantity of 0·61 cubic inch (10 cubic centimetres), which he introduces into 60 cubic inches (990 cubic centimetres) of air, when each cubic centimetre will contain 0·01 per cent. of fire-damp, which is the mixture he introduces into the vessel *G*. On rendering the platinum wire incandescent for 20 seconds, and waiting until the cooling takes place, the observer will see that, after ten minutes, the level of water will have exceeded the original level by 0·01 inch, so that the apparatus really does give indications correct to within 0·01 per cent. When the same operation is repeated with hydrogen, the original level will also be exceeded, but to a slightly less extent ; and, indeed, it is well known that one volume of this gas causes on combustion a contraction of $1\frac{1}{2}$ volumes due to the production of water-vapour, which is condensed, while methane (fire-damp) gives a contraction of 2 volumes. When operating in the same manner with carbon monoxide, such small quantities cannot be detected, as one volume of this gas only gives a contraction of $\frac{1}{2}$ volume when the carbonic acid is not absorbed. Therefore, for detecting 0·01 per cent. of carbon monoxide, the vessel *G* must have a volume of at least 24 cubic inches (400 cubic centimetres).

Graduation of the Apparatus.—The tube may be graduated directly into cubic centimetres, and each cubic centimetre into twenty or twenty-five equal parts; and, in order to obtain the exact volume of the bell-glass vessel *G*, it is sufficient, when this is full of water, to empty the liquid into a graduated test-tube. If an approximation of 0·10 per cent. be considered sufficient, all that will be required is to give the bell-glass a capacity of 2·44 cubic inches (40 cubic centimetres) and the graduated tube one of 0·61 cubic inch (10 cubic centimetres), when each cubic centimetre will be found divided into ten equal parts. In this manner as much as 9 per cent. of fire-damp may be burnt, while for a larger proportion air must be added; but in any case it will be advisable to absorb the carbonic acid.

2.—THE LABORATORY FIRE-DAMP INDICATOR.

This indicator consists of a measurer, or graduated tube *M*, the capacity of which is about 3 cubic inches (50 cubic centimetres), having a larger diameter at the top than at the bottom, and, put into communication by its lower end with a flask that can be raised or lowered, and at the top it terminates in a capillary tube in the form of a letter Γ , fitted near the intersection with a stopcock, as shown in Fig. 2. Forming a continuation to the right is a horizontal glass tube carrying two vertical tubes put in communication, the first with a bell-glass containing tubes and resting on an open-mouthed glass jar *A* filled with potash-solution; and the second with the combustion vessel, or small widened tube *B* (another view of which is shown in Fig. 3), the bottom being closed by a cork having three holes. Through two of these holes pass the brass rods which support the coil of platinum wire; and to the third is fitted the stalk of the second bell-glass, surrounded by an open-mouthed glass jar *D*, containing water. A wooden stand, carried by a shelf, keeps in place all the parts, which may be enclosed in a small portable box.

Working of the Apparatus.—When the measurer *M* is put into communication with a bell-glass *C*, into which has been transferred the gas to be analysed, by turning the stopcocks and moving the adjustable flask the potash-solution is made to rise to the level of the cock in the first bell-glass, and all the other parts—burner, horizontal glass tube, and graduated tube—are filled with water. A predetermined volume of the gas to be analysed is then passed into the measurer *M*; and, after a few minutes, the observation is made, which is effected by bringing to the same horizontal plane the level of the water in the flask and that in the measurer *M*. The gas is

then made to pass into the bell-glass in the potash jar *A*, and brought back into the measurer, when the difference between the two volumes will give the carbon dioxide content. The gas is next passed over the platinum-wire coil, which is made incandescent, and then again into the potash bell-glass, when a second diminution of volume will occur, one-third of which will give the methane or fire-damp content in the gas to be analysed. In order to drive the gas out of the capillary tube, the end of the horizontal tube may be put into communication with a glass vessel full of water, and an aspirating effect exerted, the water, thus drawn in, displacing the gas. If it be required to obtain the oxygen content at the same time, an additional bell-glass and jar *O* (Fig. 2) must be employed containing a suitable reagent—potassium pyrogallate or ammoniacal chloride of copper—and in this case the residue will be nitrogen, so that a complete analysis of the gas may be obtained.

The author has also arranged the apparatus in such a manner that a quantitative analysis may be made of lighting gas, or that from Siemens furnaces; and in the former case a bromine bell-glass and jar must also be added.

The graduation may be made as desired. The widened portion of the measurer *M* may have a volume of $2\frac{3}{4}$ cubic inches (45 cubic centimetres); and the narrow portion, one of 0.91 cubic inch (15 cubic centimetres), each cubic centimetre being afterwards subdivided into ten equal parts. In order to ascertain from the diminution of volume the amount of methane present, it will be observed that one volume of this gas will give rise to a diminution of three volumes—two of water vapour, which is condensed, and one of carbonic acid, absorbed by the potash-solution. One subdivision represents 0.2 per cent. of the total volume; and, if the gaseous mixture contained more than 9 per cent. of methane, then a known volume of air or oxygen must be added in order to burn it.

3.—APPARATUS FOR COMBUSTION OVER MERCURY.

In order to meet the views of chemists, who consider that it is only over mercury that strictly correct analyses of methane can be made, the author has devised a very simple method which permits of determining the content of this gas in a given volume of air; and the apparatus in question has this great advantage, that it may be made in any laboratory, provided that there be available a glass tube, platinum wire, a mercury receptacle, and a source of electricity.

The apparatus consists of a piece of glass tube about 8 inches (2 decimetres) long and 0.10 inch (2 to 3 millimetres) in diameter—into

which is introduced a platinum or palladium wire about 0.008 inch (0.2 millimetre) in diameter, and projecting nearly 2 inches (from 4 to 5 centimetres) beyond each end of the glass tube—the whole bent into the form of a letter U, as shown at *B*, in Fig. 4. The end or branch which is to be introduced into the graduated tube *A*, is slightly shorter than the other, in order to facilitate manipulation. At its exit from this end, the platinum wire is formed into a small coil or spiral, 0.01 inch above the end of the tube, and then descends, in a direction parallel with this tube, for a distance of, say, 1 inch (2 to 3 centimetres), and is wound round the glass, its other end being free.

Now suppose that the graduated glass tube *A*, of 1.6 cubic inches (from 25 to 30 cubic centimetres) capacity, has each centimetre divided into ten equal parts. For a capacity of $1\frac{1}{2}$ cubic inches (25 cubic centimetres), each division will represent 0.4 per cent. of the whole volume. It is easy to obtain a tube fulfilling these conditions by giving it such a diameter that, on the one hand the small branch of the tube carrying the wire may be introduced into it, and on the other that it may be almost completely immersed in the mercury receptacle. When the gas to be analysed is transferred to this tube, its volume is measured; and it must be completely submerged in the mercury by pressing upon it from above with a cork, thus preventing the heat of the hand from being communicated. After being submerged for two or three minutes, the tube is allowed to emerge, and the mercury is brought to the same level in the tube and in the receptacle. The gas must be saturated with water-vapour both before and after the operation.

The graduated tube *A* must now be fixed, and the burner *B* introduced into it, it being first filled with mercury, so as to prevent the gas issuing from the graduated tube either before or after the wire is made incandescent. In order to accomplish this, one of the poles of the source of electricity is dipped into the mercury receptacle, while the other is inserted in the branch of the U-burner which is outside the graduated tube. When the wire has remained incandescent for two or three seconds, the burner *B* is withdrawn, and the graduated tube *A* is again immersed in the mercury, note being taken of the diminution in volume. If there were originally 25 cubic inches, and only 24 remain, the one division wanting will answer to 0.4 per cent. of methane or fire-damp. In order to check the operation, and make sure that all the gas is burnt, the wire may again be made incandescent, when the volume should be the same.

If a still nearer approximation be desired, the tube *A* should be longer

and of slighter diameter, in which case, however, uncertainty as to the temperature would be greater ; and this difficulty does not arise when conducting the operation over water. If it be desired to determine the carbon dioxide content, recourse may be had to the Bunsen method of drying the gas, both before and after the operation, and using a small quantity of potash ; but this method is rather tedious.

4.—PORTABLE FIRE-DAMP INDICATOR.

Although in a laboratory, with an atmosphere consisting of a given mixture of air and fire-damp, an observer gifted with good sight may obtain indications revealing very small quantities of fire-damp, he will no longer find himself under the same conditions in the underground workings of a mine, where carbon dioxide may be present, and also coal-dust, likely to obscure the view ; and, lastly, the shield of the lamp prevents any observation from being made above a certain height. It is seldom that two miners agree as to the height of the gas-cap in an observation in the same working-place. The apparatus now to be described permits, however, of ascertaining whether fire-damp be present in the cavities, while it gives indications from $\frac{1}{4}$ per cent. and upwards.

This fire-damp indicator consists mainly of a glass-vessel *A*, having a capacity of about $1\frac{1}{2}$ cubic inches (from 20 to 25 cubic centimetres), terminating in a graduated tube of small diameter, which is inserted, to about the middle of its length, in an indiarubber plug or stopper, closing a flask, *B*, of the same substance, having a capacity of about $3\frac{1}{4}$ cubic inches (from 50 to 60 cubic centimetres) as shown in Fig. 5. The top of the glass-vessel *A* is also closed by an indiarubber plug or cover having three holes, into two of which are inserted metal rods that reach to nearly the crown of the bell, and hold between them a coil of platinum wire *C*, the length and diameter of which are such that it may be rendered incandescent by a battery. In the third hole is inserted a small tube *D*, with stopcock, which rises above the cover, for taking samples of the air from the roofs of headings or any point of a working place. All the tubes outside the indiarubber flask are surrounded by a brass casing *E* provided with windows for permitting observations to be made of the graduated glass *A*, and the platinum wire *C* when made incandescent.

When an observation is taken, the apparatus must contain water up to one of the divisions of the graduated tube. By opening the stopcock, and compressing the indiarubber flask, the observer drives off the air ; and, when it reaches the top of the tube, the stopcock must be closed. The end of the tube is then held at the point where it may be desired

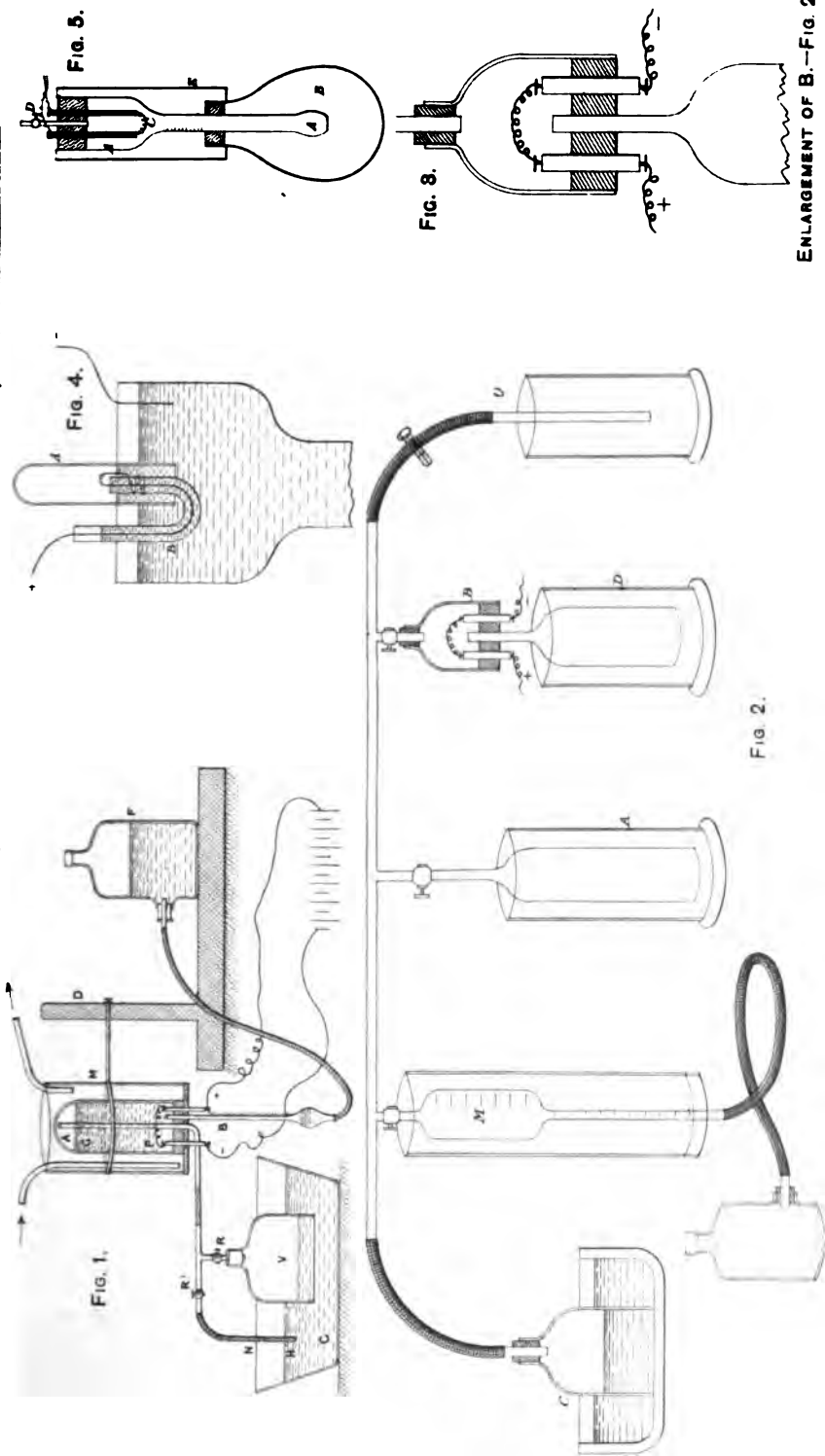
to secure a sample of gas, care being taken to hold it by the metal case, and not by the india-rubber flask, which would expand owing to the heat of the hand. The stopcock must be opened so as to allow air to enter, and must then be closed, when a volume of air will be imprisoned. After waiting a minute or two, until the level be constant, the observer marks it with the index and then makes contact between the platinum wire and the battery. The wire must remain incandescent for seven or eight seconds, when contact must be interrupted and the cooling down waited for, which may last seven or eight minutes. If only $\frac{1}{2}$ per cent. of fire-damp be present, the gas will return to the level of the index after three or four minutes, afterwards exceeding it; if there be $\frac{1}{4}$ per cent. the observer must wait from six to seven minutes; and, lastly, if there be no fire-damp whatever, the gas will only return to the mark after about eight minutes.

The author has used with success small pocket-accumulators enclosed in a box, made by Mr. Trouvé, of Paris; but several must be kept in reserve to provide for the event of one failing. He has also used Tudor accumulators, which, however, are heavier and more bulky. Lastly, magneto-electric machines may be used; but, as they are rarely portable, one must be placed underground near the working-places and shifted for each observation.

It should be noted that, when the platinum wire is made incandescent, the gas will first expand; and care must be taken that it does not escape from the graduated tube, in which case the level would rise above the index, thus indicating the presence of fire-damp when not actually existing. An observation made with atmospheric air alone will show whether the apparatus is in working order. Moreover, a little practice is sufficient to make the observer familiar with the apparatus and the source of electricity employed; and as many as twenty observations may be made during an inspection. By way of check, observations may be made, correct to within 0·10 per cent., by emptying flasks full of water (so as to allow the gas to enter) in the various working-places, and analysing the samples thus taken in the laboratory, where the operations can be conducted with greater precision.

Prof. F. CLOWES (Nottingham) stated that he fully appreciated the ingenuity of the apparatus described by Mr. Coquillion, and further acknowledged that the scientific principles on which the estimation depended were sound and satisfactory. He considered the apparatus

To illustrate Mr. J. Coquillion's Paper on the "Determination of Fire-damp in French Collieries."



suitable for giving accurate and delicate measurements of fire-damp in air, if it could be used in the laboratory and the necessary time could be given for carrying out the processes. But he had always maintained that Mr. Coquillion's method was unsuitable for use in the mine. It was not sufficiently rapid in yielding its results; and it was decidedly less convenient in practice in every way than the best forms of flame-cap methods. The objections raised by Mr. Coquillion against the use of the flame-cap test did not apply to that test when the hydrogen flame was employed for the purpose instead of the oil or alcohol flame. The indications were furnished by the hydrogen flame-test with ease, rapidity, and certainty, and could be carried out by anyone without difficulty. There seemed to be no doubt in the minds of those who had to make tests for fire-damp underground that the flame-cap method was on all grounds to be preferred, and he must say that he fully concurred in this opinion.

Mr. G. E. J. McMURTRIE (Cinderford) wrote that he considered that at the present time no instrument for detecting small percentages of gas could equal the Clowes hydrogen oil-lamp for portability and compactness, as with the Pieler alcohol lamp it was necessary to carry an oil-lamp for lighting purposes, while the Clowes lamp served both purposes, and gave more accurate results. The Coquillion portable apparatus, though compact and light, when compared with his laboratory and return-air apparatus, yet was an addition to the ordinary oil-lamp. The same objection applied to the Liveing gas-detector, which detected similar small percentages of gas. It appeared to him (Mr. McMurtrie) that the constant changes that took place in the composition of the air in a mine precluded any advantages resulting from laboratory tests of the air of the mine, either by the Coquillion or the Shaw gas-detector, as long before the laboratory test had been made a different state of affairs had arisen in the mine. Moreover, such tests must be carried out by additional officials, and so add to the cost of mining, while producing, in his opinion, no good results. Tests of return air-currents certainly were required, though elaborate and additional apparatus was if possible to be avoided, and the Clowes lamp appeared to be the best apparatus for this purpose at the present time. It was much to be regretted that the presence of coal-dust affected the accuracy and working of both the Pieler alcohol and the Clowes hydrogen lamp, as it was in dry and dusty mines that the presence of small percentages of gas required especially to be detected.

Mr. J. COQUILLION wrote, in reply to the remarks made by Prof. Clowes, that not knowing the lamp which he had designed, he was unable to criticize it, and he only wished to point out that lamps, the upper portions of which were protected by a shield, did not allow of the upper portion of the lamp being observed to see if any fire-damp was present. Moreover, he had often noticed that observers differed, some seeing a flame-cap where others could not see one, whereas his apparatus showed a definite diminution in volume, if the atmosphere contained gas. The objection might be raised against his system that in it electricity is necessarily employed. This is no difficulty in laboratories or works; but it may be objectionable in the mine, where accumulators must be used, or a magneto-electric machine might be set up near the shaft-bottom.

A vote of thanks was accorded to Mr. Coquillion for his paper.

The following paper by Prof. F. Clowes on "The Detection and Estimation of Carbon Monoxide in the Air by the Flame-cap Test" was taken as read :—

THE DETECTION AND ESTIMATION OF CARBON MON-OXIDE IN THE AIR BY THE FLAME-CAP TEST.

By PROF. FRANK CLOWES, D.Sc.

Experiments have recently been carried out by Dr. Haldane which prove, or rather confirm, the extremely poisonous nature of carbon monoxide when it is breathed in the air. He has shown that as small a proportion as 0.20 per cent. of this gas in the air is sufficient to produce symptoms of poisoning, and even under suitable conditions to produce serious results. And he has further fully established that this gas is frequently, if not usually, the main cause of death in colliery explosions and in coal or gob-fires. The importance of detecting the presence of the gas in the air of the coal-mine is therefore evident. Dr. Haldane gives at least one practical means of preventing the explorer from remaining too long in an atmosphere which has been rendered poisonous by carbon monoxide. He has shown that a mouse is rendered helpless by breathing such an atmosphere in one-twentieth of the time required for a man to assume the same condition. Accordingly if a mouse, carried in a wire cage, becomes helpless, it gives warning and ample time for a man who carries the mouse to beat a retreat before he is paralysed by this gas.

Dr. Haldane has further given a scientific test by means of diluted blood, which not only indicates but also measures carbon monoxide in the air. This test has been of the greatest value in the hands of its discoverer in investigating the conditions of danger arising from carbon monoxide, and in indicating the cases where death or danger have resulted from carbon monoxide in the coal-mine. For the purposes just mentioned the blood-test has been, and will continue to be, of the greatest value. In fact it is at present the only method available for furnishing the necessary information as to the cause of death, when poisoning by carbon monoxide is suspected. This method, however, is unfortunately not applicable in the workings of the mine, since it requires daylight in order to yield its indications, and it also does not furnish its indications with sufficient rapidity for ordinary practical purposes.

In a former paper, on the application of the hydrogen flame-cap test to the detection of inflammable gases in the air, the writer mentioned that carbon monoxide gave a distinct flame-cap over the hydrogen-flame; and those who are more especially interested in the rapid detection of carbon monoxide in the air have accordingly asked whether this test will

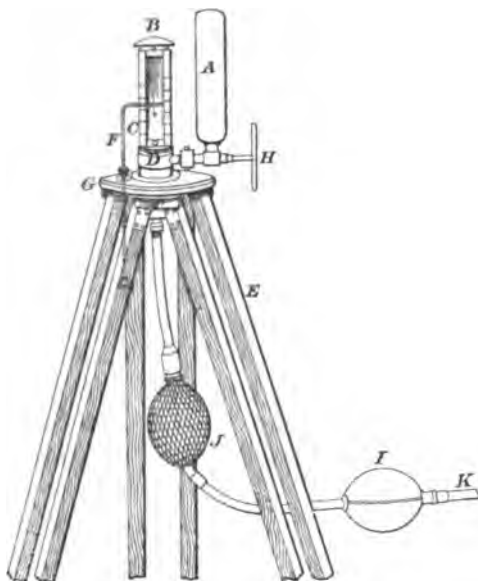
not furnish a ready and rapid means of detecting carbon monoxide. In reply to such enquiries, it may be stated that the hydrogen test is sufficiently delicate to ensure warning against danger. The lower limit at which carbon monoxide begins to be dangerous (about 0·20 per cent.) is a quantity which produces over the standard 0·40 inch hydrogen-flame a cap 0·50 inch in height and distinctly visible. Such a cap would be easily seen in the hydrogen safety-lamp. There is this difficulty, however, connected with the test. Such a cap may be produced by the presence of any other inflammable gas, as well as by carbon monoxide. Accordingly the appearance of the cap may act as a warning, but it is no proof of danger, unless carbon monoxide is the only inflammable gas which may be present. The height of the cap increases regularly with increase in the percentage of carbon monoxide in the air, and hence the cap is not only an indication, but a measure of the carbon monoxide under the conditions just stated.

A modified form of apparatus for applying the hydrogen-flame test has recently been brought into use. It is specially intended for testing the air present in inaccessible or dangerous places, or in places where the air may be poisonous. It has been more especially used for testing the air in electric street culverts, sewers, and in certain parts of gas-works. It is specially suitable for testing air which may be poisonous, since it does not require the operator to enter the atmosphere to be tested. The air is drawn away by a simple pumping arrangement, and is then made to pass over the hydrogen-flame, under conditions suitable for observing and measuring, if necessary, any flame-cap which may be formed. The apparatus, if it were deemed useful for similar purposes within the coal-mine, might easily be rendered safe by means of an upper wire-gauze. In its usual form it is only protected from firing backwards to the air-supply by means of a lower gauze.

The apparatus is shown in Fig. 1. It is mounted upon an ordinary portable camera-stand, which raises it to a height level with the eye and suitable for observation. The hydrogen-flame, fed from the little cylinder *A*, burns within the brass cylinder *BD*, which is furnished with a transparent talc or mica front through which the flame-caps can be observed. The hydrogen flame is regulated to standard height by bringing its tip level with the bottom *D* of the window: this is effected by means of the valve *H*. The air to be tested is pumped through the rubber tube *K* by squeezing the valved rubber-ball *I*, and the pressure of the air is rendered uniform by passage through the flexible rubber reservoir *J*, from which the air-stream passes through several discs of wire-gauze into

the foot of the cylinder *BD*. It is thus possible to pump a regular supply of the air which is to be tested over the hydrogen-flame. If any cap is seen, the air is pumped continuously over the flame until the cap remains constant in height. The level of the top of the cap is then registered by drawing down the bent wire *F* until its horizontal part just touches the top of the cap. The height thus registered can be read off on a scale graduated to 0.1 inch on the metal at the edge of the window. The range of indications is increased by making arrangement for the use of a standard hydrogen flame either 0.40 or 0.20 inch in height, as may be necessary in order to bring the cap within the limits of the scale and of the cylinder.

If the apparatus be used in a dark room or space, the observations are made in the open; if the observations must be made in an illuminated space, a camera cloth is thrown over the head of the observer and the cylinder *BD*, so as to enable the caps to be seen and measured. The small pocket hydrogen supply is shown in use in the figure; this may be replaced by a larger supply if there is no object in keeping the weight of the apparatus within small limits. It need hardly be added that these steel cylinders containing compressed gas are supplied under regulations which absolutely ensure their freedom from danger.



A vote of thanks was accorded to Prof. Clowes for his interesting paper.

Mr. W. GALLOWAY read the following paper on "Appliances for Winding Water":—

APPLIANCES FOR WINDING WATER.

BY W. GALLOWAY.

Circumstances occasionally arise during the existence of a mine in which it is expedient to raise a part or the whole of the water by winding it to the surface up a vertical shaft, and the object of the present paper is to show how this arrangement has been effected in one instance that occurred within the experience of the writer, and how it may be done in others. Some of the circumstances referred to may be shortly enumerated as follows :—

(a) A shaft is in course of being sunk, and it is intended either to keep back the water by means of coffering or tubbing, or to establish one or more permanent pumping-engines in chambers to be excavated at some point or points deeper than that at which the water is first encountered.

(b) An unexpected influx of water takes place in the workings of a mine which threatens to drown them before a pump of sufficient power to cope with it can be obtained or erected.

(c) It is known beforehand that the influx of water will only be of a temporary character, as, for instance, when old workings are tapped with the object of draining them ; and that the cost of purchasing and establishing a pump sufficiently large to deal with it would exceed the cost of winding it.

(d) An old mine containing an accumulation of water is to be drained ; and lastly,

(e) A small feeder existing at the bottom of a deep shaft produces so little water that it can be raised in a tank in the cage without interfering with the ordinary operations of winding.

It is assumed that in all these cases the mine already possesses a winding-engine suitable for the purpose ; and that, in the first case (a), either the permanent winding-engine can be employed exclusively in this service while some other temporary engine is employed in raising the rubbish, or *vice versa*, according to the relative importance of the two services.

In two former papers contributed by the writer to the South Wales Institute of Engineers,* he described the various appliances for winding water which he had adopted in sinking No. 1 pit of Llanbradach colliery. That pit † was sunk to a depth of 1,716 feet before the No. 2 pit was commenced. The present paper will be devoted partly to a description of the appliances for raising water used in connexion with the sinking of No. 2 pit, and partly to that of a modification of the system of winding water from a cistern resting on a beam at one side of the shaft, which the writer employed in the No. 1 pit in conjunction with the method of lengthening guide-ropes patented by him in 1876.

The ground passed through in sinking No. 1 pit consisted for the most part of very hard, fissured, water-bearing sandstone down to a depth of 600 feet from the surface. It was therefore anticipated that a considerable quantity of water would be met with during this part of the sinking of No. 2 pit, and preparations were made for dealing with it by driving a heading from No. 1 pit to a point vertically below the site of No. 2 pit, at a depth of 600 feet, and boring a hole (6 inches in diameter) by means of a diamond drill from the bottom of No. 2 pit when it was 150 feet deep, down into the heading.

The water accruing from No. 2 pit then passed down through the bore-hole, flowed along the heading, and into the circular lodgment which surrounds the walling of No. 1 pit, and was thence drawn off as desired by opening a stopcock in a pipe which led from the lodgment to the well of a Worthington pumping-engine placed in a chamber at the side of the shaft, 42 feet lower down.

The dimensions of the shafts and some particulars of the appliances then existing are as follows :—

No. 1 pit is 17 feet in diameter ; No. 2 pit, 20 feet ; the distance between their centres is 165 feet ; the Worthington pumping-engine had a surplus capacity of about 400 gallons per minute for dealing with water from No. 2 pit (this engine had replaced another smaller one, which was described in one of the former papers) ; the winding-engine of No. 1 pit could raise about 300 gallons per minute from a depth of 800 or 900 feet by means of a cylindrical water-barrel with a capacity of 600 gallons ; the construction of the temporary head-gear of No. 1 pit was such as to admit of the employment of only one winding-rope and one bucket, which worked in the centre of the shaft ; and lastly, two wire ropes which had served the double purpose of manipulating the walling-

* *Proceedings*, 1888-89, vol. xvi., pages 107 and 268.

† *Trans. Fed. Inst.*, vol. xii., page 294.

stage and acting as guide-ropes to the sinking buckets and water-barrels while sinking was going on, according to the writer's system, remained suspended in the shaft with the walling-stage still hanging at their ends near the bottom, and served as guides to the cylindrical water-barrel. At the surface, they passed over pulleys at the top of the head-gear, and extended thence to the two drums of a steam-crab situated behind the winding-engine, upon which the spare part of each of the ropes was respectively wound.

No difficulty had been experienced in dealing with the water met with in No. 2 pit down to a depth of 400 or 450 feet. Between the depths of 210 and 390 feet, feeders of water producing 18,000 gallons per hour had been passed, and were successfully walled out with brick and cement. But when the shaft reached a depth of 400 to 450 feet, an open fissure was encountered which produced water in such abundance that it became necessary to allow No. 1 pit to fill up nearly to the level of the Worthington pumping-engine at 642 feet, and to bring the water-barrel to the rescue of the pump. In the meantime, the 600 gallons barrel had been replaced by another with a capacity of 800 gallons. The fissure, from which the greater part of the water was coming, followed the shaft almost vertically downwards, widened somewhat in descending, and poured out a continuous stream, which increased with every round of shot-holes. When the depth of 558 feet was reached, the quantity of water flowing into No. 1 pit amounted to about 55,000 gallons per hour, and the pump and water-barrel were both taxed to their utmost limits. At this juncture, the pump was unfortunately stopped for a short time to effect some slight repair, without the precaution having been taken of plugging the bore-hole, and the water immediately rose and drowned it. Water-winding was continued for a few days with No. 1 pit winding-engine and with the two small sinking-engines at No. 2 pit, which together raised about 45,000 gallons per hour; but it was evident that the water could not by these means be reduced below the level of the pump, and it was therefore resolved on November 19th, 1891, to suspend operations, to erect the permanent head-gear on No. 1 pit, and to provide appliances for winding the water from that pit of sufficient capacity to deal with it. The head-gear was not finished until the beginning of April, 1892.

In the meantime, two water-tanks (Figs. 1 to 10, Plate II.), specially designed by the writer, and intended to work between two wire rope-guides were constructed, and the conditions which they were required to fulfil were as follows :—

- (1) To have a capacity of 1,000 gallons each.
- (2) To fill and empty without having any tendency to push the guide-ropes out of their normal position.
- (3) To fill and empty in the shortest possible time.
- (4) To be emptied automatically.
- (5) To deliver the water as nearly horizontally as possible, and with such velocity as to carry it clear of the opening through which the bucket was drawn on reaching the surface.

The second requirement was attained by having openings for the ingress and egress of the water at opposite sides and of equal area; the third, by using very large valves; the fourth, by the arrangement of levers, rods, and weights shown in Figs. 1 to 10 (Plate II.); and the fifth, by placing a second bottom below that upon which the valves rested, with its floor sloping equally from a central ridge towards the opposite outlets. In order to oppose the greatest resistance to any tendency which the tanks might have to turn round out of the plane in which they were intended to work, the guides were put at their ends, and hence each outlet was divided into two equal parts by a central rib on which the guide-shoe *a*, was fixed.

The sinking-guides which remained in the shaft with the walling-stage suspended at their lower ends* were originally situated symmetrically on each side of the centre of the shaft in a plane which passed through the winding-ropes, but were now drawn forward, that is away from the winding-engine by a distance equal to one-half of the length between the guide-shoes on the tanks, and were fixed in this position by means of glands on the platform near the top of the head-gear (Figs. 11 and 12, Plate II). Two additional guide-ropes similarly situated on the opposite sides of the winding-ropes, that is to say, nearer to the winding-engine, were lowered to a depth of about 800 feet below the surface, and fixed in the same way as the two first-named. For the purpose of keeping the ropes taut, a frame, 30 feet long, made out of parts of the temporary head-gear, having a box containing 5 or 6 tons of old iron at the bottom and arms standing out at right-angles at the top, and provided with guide-shoes which embraced and held the first guide-ropes at the proper distance apart from them, was suspended at their lower ends.

The winding-ropes (locked-coil) were taken of such length to begin with, that when one of the tanks was being emptied at the surface the other was from 30 to 45 feet under the surface of the water. The two

* *Proceedings of the South Wales Institute of Engineers*, 1888-89, vol. xvi., page 107.

tanks, with 15 tons safety-hooks intervening, were suspended to the winding-ropes, the levers for emptying them automatically were put into their places and the winding of water was begun and carried on continuously. When the surface of the water sank so that the tank dipping into it was only partially filled, a lap of rope was taken off the drum of the winding-engine (14 feet in diameter), which caused the tanks to descend into the water to a depth of about 42 feet at first. On one occasion, two laps of rope were taken off with the object of saving time, but it was found that the necessarily slower rate of winding under water, absorbed in the aggregate more time than was required to take off the lap of rope, and thereafter the ropes were lengthened by only 42 feet at a time.

During the suspension of operations, the water had risen in both shafts to within 120 or 130 feet of the surface, namely, to its natural level in the ground. As a consequence, the fissures in the rock which had been drained by degrees while the shafts were in process of being sunk had become filled once more and required to be drained a second time.

On April 14th, 1892, the two small sinking-engines of No. 2 pit began to wind water with two cylindrical water-barrels, both of which were emptied automatically at the top of the pit, and delivered their water nearly horizontally in the same way as the tanks in No. 1 pit. On April 19th, 1892, the winding of water was commenced in No. 1 pit.

The surface of the water was lowered in No. 1 pit as follows :—

Date.					Depth to the Surface of the Water. Feet.
1892, April 18th	...	...	...	...	195
„ April 19th	...	...	...	...	207
„ April 23rd	...	...	...	...	366
„ May 5th	...	...	...	...	588
„ May 22nd	...	...	...	...	636

The minimum quantity of water raised was 70,000 gallons per hour, and the maximum 110,000 gallons per hour. The minimum quantity raised by the two tanks in No. 1 pit was 60,000 gallons per hour at the commencement, before the enginemen had become familiar with the work, and this gradually increased up to 94,000 gallons, or 94 tanks per hour.

The quantity of small coal consumed by all the engines amounted to as nearly as may be 10 pounds per horse-power of actual work done in raising water per hour. For the purpose of ascertaining this value, the writer caused the number of tanks raised at each pit to be carefully counted day and night for upwards of a week, the distance of the top of the water below the surface to be measured at regular intervals by means

of a float, and the weight of coal supplied to the boilers during the same period to be recorded.

The *débris* from the last shots that had been fired in No. 2 pit before the suspension of work still remained in the bottom, preventing the water from flowing freely into the bore-hole, and thus it was found that after the water in No. 1 pit had been lowered to the level of the Worthington pumping-engine, there still remained a depth of 15 or 20 feet of water in No. 2 pit, although the surface of the water in No. 1 pit was over 90 feet lower. It took several days' work to remove the obstruction by operating partly in the shaft from above downwards, and partly in the heading from below upwards through the bore-hole.

The pumping-engine was completely overhauled and cleaned, and started to pump on June 8th, 1892. Just before it started, the tanks in No. 1 pit were easily keeping the water down at a depth of 70 or 90 feet below the pump-chamber, while raising 70,000 gallons an hour from a depth of 720 feet, or say 251 effective horse-power.

Sinking was resumed on June 11th, 1892, and the water subsequently increased to 75,000 gallons an hour, and remained at that amount until the sinking had been carried down below the level of the heading and the coffering had been built and plugged.

Immediately thereafter, the quantity of water accruing from all sources in both shafts above the level of the pump fell to less than 12,000 gallons per hour, but within a few days it again rose to about 24,000 gallons per hour in consequence of a fracture having taken place in the brickwork near the bottom of the coffering. It was thought inadvisable to attempt to make good this leak lest the pressure should burst the brickwork somewhere else.

To show the efficiency of the coffering, it may be mentioned that some three months afterwards one of the plugs blew out, late on a Sunday night, when the writer happened to be at the colliery. The walling-stage, which was worked in the same way as that in No. 1 pit already referred to, was quickly brought up to the point. A baulk of wood 6 inches square by 9 feet long was reduced to rather over 3 inches in diameter for a length of about $8\frac{1}{2}$ feet, the last foot in length being drawn out to a sharp point. Two holes were bored in the square part to receive bars of round iron about 4 feet long by $1\frac{1}{4}$ inches in diameter. Six of the sinkers working under the direction of the foreman tried in vain for nearly two hours to cause the plug to enter into the hole in the plug-box against the force of the issuing water. No. 2 pit, which was 200 or 210 feet deep below the heading which connected it to No. 1

pit was soon filled, and the water commenced to flow over into No. 1 pit. The writer then directed a strong fulcrum, consisting of pieces of log, to be built on the floor of the walling stage and strengthened by supports against the side of the shaft opposite to that from which the water was issuing, and by means of a screw-jack the plug was gradually forced into the hole until it would go no further. The remaining part of the timber was sawn off close to the plug-box, and two long iron wedges were driven into the plug. Estimating the cubical contents of the parts of both shafts that were filled with water during the four hours in which the hole remained open the writer arrived at the conclusion that about 202,500 gallons must have escaped, or at the rate of 50,625 gallons an hour—all of which came through a hole 3 inches in diameter. About eighteen months afterwards, a small hole was bored in one of the plug-boxes and a pipe with a pressure-gauge attached was fitted into it, which showed the pressure to be 160 pounds per square inch, at a height of about 30 feet above the bottom of the coffering.

The appliances employed in winding the water from No. 1 pit, as well as some of their details, are shown in Figs. 1 to 6 (Plate II.). *a, a*, are the guide-shoes; *b*, bottom upon which the valves rest; *c*, lower bottom sloping towards the outlet-openings from a central ridge; *d*, openings in the upper bottom; *e, e*, outlet-openings from the space between the two bottoms, each furnished with a mouth-piece; *f, f*, the valves; *g, g*, levers for automatically opening the valves; *h, h*, fulcrums for levers; *k, k*, blocks of wood upon which the levers come to rest when the valves are opened; *l, l*, rods connecting the levers to the valves; *m, m*, and *n, n*, angle-iron stays. In Figs. 7, 8, 9, and 10 (Plate II.), which are on a larger scale, *o, o*, are flat faces on the ends of the levers; *p*, a distance-piece between the two halves of the lever; *q*, pin and distance-piece, the former passing through the fulcrum and the two sides of the lever, the latter holding the two sides at the proper distance apart; *r*, forged piece forming the connexion between the lever and the rod *f*; *s*, forged piece connecting the rod *f* to the valve; *t*, upper plate; *v*, lower plate; and *u*, sheet of indiarubber between the two; the three together constituting the valve.

Figs. 11 and 12 (Plate II.) are views of the head-gear showing how the water-tanks were emptied automatically on two opposite sides at the surface. *a*, is one of the water-tanks; *b, b*, baulks of timber hinged at their ends *c, c*, shod with a sufficiently broad plate of iron on their under sides at their opposite ends, to enable them to embrace both sides of the levers; and having weights *e, e*, suspended from them by chains,

heavy enough to open the valves when the tank was raised to the proper height above the shoots which carried away the water. *f, f,* are the shoots which received the water on opposite sides and conveyed it to arched drains under the surface-level. The positions in which the guide-ropes were fixed, and the glands *d, d,* by means of which they were fixed are shown in both figures. The water easily leaped across the space between the sides of the tank and the shoots, which was of sufficient width to give good clearance to the projecting ends of the levers.

The tanks, with all their mountings, weighed about 3 tons each, and the weight of water carried by each of them amounted to nearly $4\frac{1}{2}$ tons. The top of each tank was covered by a plate with a rectangular hole in it, just large enough for a man to pass through, and the position of this hole was naturally such that the rods which connected the levers to the valves passed through it. When the tanks arrived at the surface they were full to the very brim so long as they were dipping under the surface of the water in the pit.

The necessary labour consisted of three enginemen working continually in shifts of eight hours each. In addition to the enginemen, two banksmen in shifts of twelve hours each, and one engine-cleaner by day were employed. The principal work of the banksmen consisted in counting the number of tanks drawn, observing when the ropes required to be lengthened, assisting in lengthening them, and keeping an eye upon the operations generally.

It has been mentioned that the maximum number of tanks drawn in No. 1 pit was 94 per hour. Allowing 9 tanks per hour for contingencies, that is, taking 85 per hour as an average for 24 hours, the quantity and cost per ton would be somewhat as follows, when the depth of the water from the surface was 600 feet:—Quantity of water raised in 24 hours 2,040,000 gallons = 9,107 tons; horse-power, 257; coal consumed at 10 lbs. per horse-power per hour, 27 tons 10 cwt.; duty of 1 cwt. (112 lbs.) of coal, 22,254,196 foot-pounds.

COST PER TON OF WATER RAISED 600 FEET.

	£	s.	d.
3 Enginemen at 5s. 6d.	0	16	6
2 Banksmen at 4s. 2d.	0	8	4
1 Engine-cleaner at 3s. 6d.	0	3	6
27½ Tons of coal* at 6s. 6d.	8	18	4
Stores and light	1	0	0
Ropes at 0·05d. per ton raised	1	17	6
Total	£13	4	2

Or 0·347d. per ton, or 0·259d. per 1,000,000 foot-pounds.

* Including cost of stoking and boiler-management.

6

These figures are given as a fair approximation, with the object of serving as a basis of comparison with other systems of raising water. The same winding-rope was used throughout the whole period of winding. It was a new locked-coil rope, $1\frac{1}{4}$ inches in diameter, weighing 23 lbs. per fathom, 1,965 feet long, and cost £194 16s. It was coiled on the drum, and the two ends were both capped and brought over the pulleys. At the end of the operation, it looked none the worse for wear. The guide-ropes were practically worn out before the operation commenced. They were cheap in the beginning, had served in sinking No. 1 pit, and one of them had been damaged. The allowance for ropes is therefore liberal.

It will be remarked that the duty does not much exceed one-third of that of a fair Cornish pumping-engine, and reached only to about one-fifth of that of a very high-class pumping-engine of the most approved type, and, therefore, one would not be justified in resorting to this method of raising water for a prolonged period of time. It had, however, the advantage of easy application, and low first cost: a Cornish engine and pumps to do the same work would have cost £5,000 or £6,000, whereas the two tanks and their accessories cost only £140. The whole of the appliances can be removed in a few days after the work is completed, by the water being walled back or an economical pumping-engine established in a chamber underground, leaving the surface unencumbered and the shaft comparatively free for coal-winding. The system can, besides, be applied within a few weeks after the emergency arises, if the head-gear is already provided with two pulleys; while, on the other hand, a pumping-engine of the same capacity would require the greater part of a year before it could be got ready and set to work.

Exactly the same arguments apply in the case of similar contrivances employed in raising water from the bottom of a shaft in course of being sunk, with the additional remark, that the valves of the tanks are simple, that they incur very little wear, that they are not affected by water containing grit, and that the whole of the appliances can be raised up the shaft as near to the surface as may be desired, so that they cannot be drowned under any circumstances that may arise.

The writer has mentioned that in sinking No. 1 pit he employed as part of the apparatus for raising water a tank resting on a beam at one side of the shaft, into which another tank running between wire-rope guides was dipped, so as to be filled, and was then raised to the surface

and emptied automatically. The beam and the collecting-tank were lowered from time to time by means of the rope of the winding-engine as the shaft was deepened. The writer was obliged to take this course, as there was no spare engine on the ground wherewith to manipulate the collecting-tank, independently of the winding-engine. If a suitable engine had been available, he would have suspended the collecting-tank from ropes and have lowered it by degrees instead of by large increments.

Figs. 13, 14, 15, and 16 (Plate II.) show the complete arrangement as contemplated. The guide-ropes from the drums of a screw steam-crab pass over pulleys on the top of the head-gear, descend the shaft to the collecting-tank, pass through shoes on one side, then under pulleys provided with shields fixed to the framework of joists, which supports the collecting-tank, then up through shoes on the opposite side, and thence to the top of the head-gear, where their ends are clamped. The writer provided four guide-ropes arranged in a similar way in connexion with the walling-stage of No. 2 pit, which worked from the time the shaft was 90 feet, until it was 1,752 feet deep. Each of the winding-tanks is provided with the same kind of valves, rods, levers, and lower sloping bottom as those which have been described. But their guide-shoes are fixed to channel-iron uprights, which project above the top so as to admit of the winding-tanks dipping into the collecting-tank while the shoes remain above the level of its upper edge.

Besides the water which accrues above its level, the collecting-tank can also receive the water from the bottom of the shaft raised up to it by means of centrifugal or other pumps actuated by steam, compressed air, an electric current, or by a rope or rod from the surface, and the height of the lift need not at any time exceed from 30 to 50 feet.

The collecting-tank and the winding-tanks may obviously be made large enough to deal with any quantity of water from 5,000 up to or exceeding 100,000 gallons an hour, provided the shaft is wide enough and the winding-engine sufficiently powerful. The use of flat rope-rolls, one keyed, the other bolted to a boss on the engine-shaft, would not only furnish the means of lengthening the ropes, with a minimum loss of time, as required, but would also to some extent tend to counterbalance the weight of the rope in the shaft and effect a corresponding economy of fuel.

At the surface, the tanks are intended to deliver the water into three troughs, one between the two tanks, the others outside. The central trough can be provided with a light hinged flap made of wood or sheet-iron hanging vertically over its centre line, which the force of the water

issuing from either of the tanks can drive against its opposite side, and thus prevent any tendency that the water may have to splash over into the compartment occupied by the other tank.

Mr. JEREMIAH HEAD (London) asked whether he rightly understood Mr. Galloway to imply that 10 lbs. of coal were used per horse-power in pumping out water. If so, he would be at a loss to see why the engines used should have been so uneconomical. Portable agricultural and locomotive engines had produced 1 indicated horse-power for as low as 3 lbs. of coal. He presumed in this case it was not indicated but actual horse-power in water lifted, yet even then the difference between 3 or 4 lbs. and 10 lbs. was not easily accounted for. He could only imagine that there had been no expansive working, no compounding, no condensing—possibly also the coal was not of good quality, nor economically used.

Mr. A. L. STEAVENSON (Durham) remarked that the cost of 1,000,000 foot-pounds at Llanbradach came to about $\frac{1}{4}$ d., which was excellent work under the circumstances. A good many of the members who had done similar pumping had found it cost $\frac{1}{4}$ d. with a mine-pump.

Mr. B. WOODWORTH remarked that if some winding-engines were measured in the same way by mineral raised, the consumption would be at least 20 lbs. of coal per horse-power-hour. He had roughly checked what he considered the best specimen of continuous diagram from a winding-engine that he had seen in the course of his experience as regards results of working with ordinary valve-gear well adjusted. He found without any allowance for landing and hooking-on, that the indicated horse-power showed practically 5 tons effort on the piston for a paying-load of coals averaging about 52 to 53 cwts., so that the indicated horse-power was at least 75 per cent. above the duty done, and if cut-off gear were used (which would not be likely for Mr. Galloway's temporary expedient) the indicated power would be the same but the steam-consumption would be reduced.

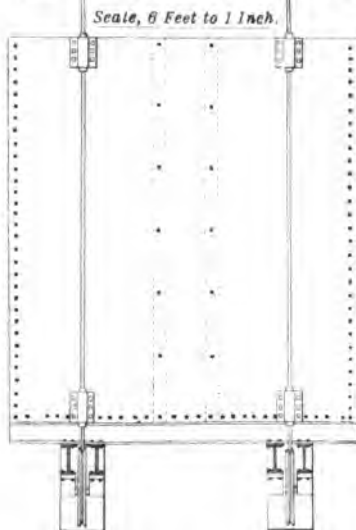
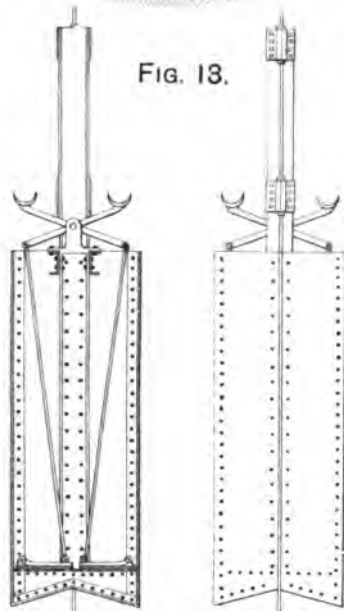
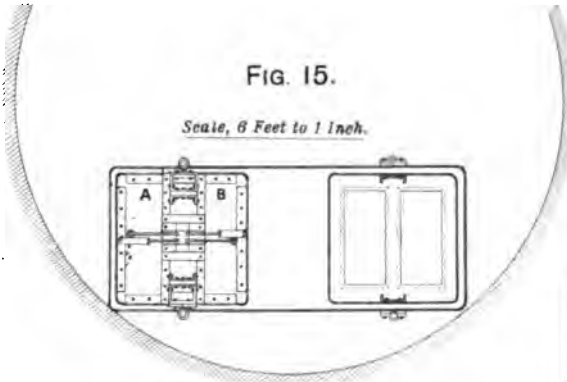
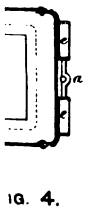
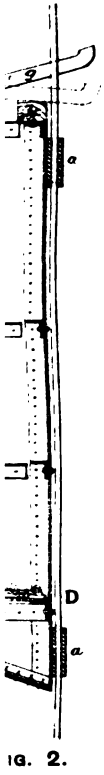
Mr. M. H. DOUGLAS (Usworth) wrote that the arrangements and appliances described by Mr. Galloway for quickly and economically drawing from a sinking-pit large accumulated quantities of water were very interesting and of great value to members who might have to

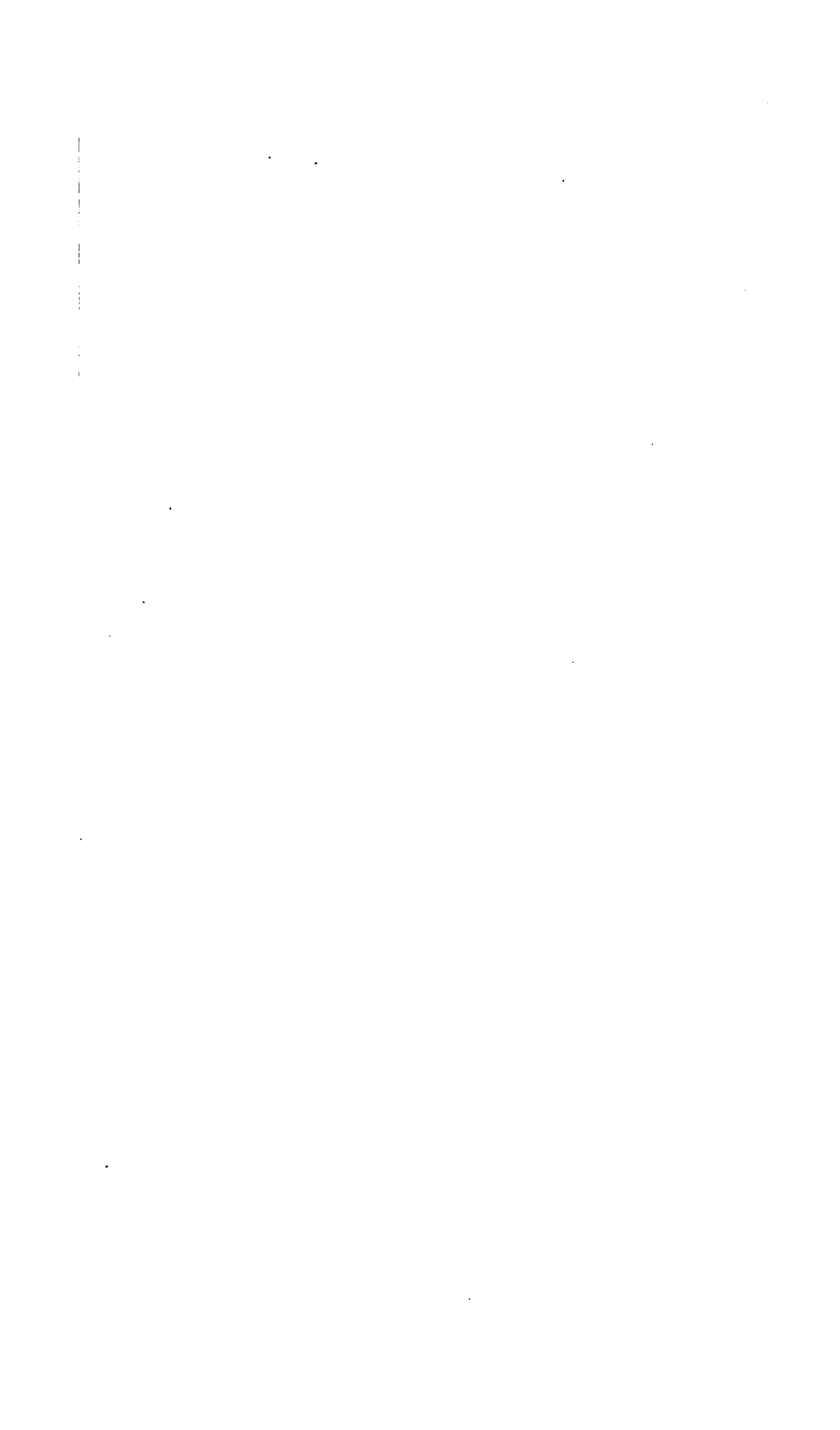
Sinking Water

B-Fig 2

D-Fig 4

FIG. 16.





undertake this class of work. No doubt, the good results obtained were in a great measure due to the use of wire-rope guides, on which the water-tanks ran in the shaft. In draining old workings, however, it was not always advisable to rush the water out at such a speed as described, on account of the pent-up gases which might be encountered under great pressures.

He (Mr. Douglas) had occasion a few years ago to unwater a new shaft that had been sunk 360 feet below the coal-seams ordinarily worked at the colliery, the total depth of the shaft being 1,050 feet. From the lower coal-seam, won by this shaft, the workings had been opened out by two exploring-places for a distance of 600 feet to the rise of the shaft, and these places were producing such large quantities of gas and water that it was decided to suspend operations for a time until suitable appliances could be procured. The shaft and workings were allowed to fill up with water to the seam above, and all working was abandoned for about twelve months. The lower 360 feet in depth of the shaft was fitted up with exceptionally strong wooden guides ready for coal-drawing, and was ventilated by means of a wooden brattice, 3 inches thick; one cage only being in use. In commencing to withdraw the water, two large water-tanks, each holding 400 gallons or 800 gallons in all, were fitted securely into the cage, and each tank was provided with large inlet and outlet flap-valves for rapid and automatic filling and emptying. The winding-engines employed had two horizontal cylinders, each 48 inches in diameter and 72 inches stroke, fitted with a horizontal drum, 20 feet in diameter, together with all the latest improvements for quick winding.

The water for a depth of 180 feet was quickly lowered, when it was found that large quantities of gas were being given off at the surface of the water. It was then decided to draw the water at night only, when all open lights were removed from the workings and on the surface, and the water was then lowered at the rate of about 6 feet every twenty-four hours. This rate continued for twenty days, the gas showing no appreciable increase or decrease until the water was lowered to within 60 feet of the bottom of the shaft. At this point, the cage got fast in the shaft, and the engineman reported a violent oscillation just previous to the sticking fast of the cage. No one was in the workings or on the pit-top at the time who could describe what the effect was at these two points. On descending the shaft and making an examination of the cage, it was found that the water had suddenly subsided close down to the inset of the seam, and the shaft-guides and

brattice were completely wrecked and blown out for a height of 60 feet. The noise caused by the gas issuing at the inset of the shaft was deafening at the point where the cage got fast.

The question of sinking one shaft down so great a distance as that described by Mr. Galloway, and putting down bore-holes from the second shaft, did not appear to be advisable, on the score of time and economy. The quick speed of winding water described could not be attained with safety, except where rope-guides were in use, and he (Mr. Douglas) suggested that in small shafts, or with shafts in which projecting buntons, water-cisterns, temporary pumps, etc., were placed, and rope-guides were not in use, the most efficient form of water-barrel was that known as the cigar-shaped, with a mushroom spindle-valve placed at the bottom for emptying it of water.

Mr. JOHN MORISON (Cramlington) wrote that the account given by Mr. Galloway of the means adopted for winding water at Llanbradach colliery was extremely interesting and valuable. The means adopted were manifestly most suitable and economical under the circumstances, although it might be remarked that the conditions were not only favourable, but very peculiar.

The peculiarity of conditions referred to was, that it appeared to have been possible to sink No. 1 pit at a distance of 165 feet from No. 2 pit, through the same strata with comparatively little water, while No. 2 pit, in course of sinking, liberated the large quantity of water recorded in the paper. He (Mr. Morison) had similar experience in finding water unexpectedly in ground which had been explored in close proximity; but it was nevertheless curious that a shaft exposing so large an area of what is described as a "fissured, water-bearing sandstone," should pass through the rock without draining it within the distance mentioned.

While, therefore, the system which Mr. Galloway explained and advocated proved applicable to the existing conditions, he (Mr. Morison) thought that the difficulties of winding large quantities of water from sinking pits whilst work was going on in the bottom would be very much greater than where, as in Mr. Galloway's case, a pioneer pit was sunk ahead of the pit producing the water, and with a connexion between them which enabled the water made in the sinking pit to be drained into the shaft where no sinking operations were in progress. Also he (Mr. Morison) doubted whether it would be practicable, under the best possible application of the system described, to deal successfully with a quantity of water approaching 100,000 gallons an hour, as was suggested by Mr. Galloway in his contemplated scheme.

The maximum quantity dealt with by the two tanks described amounted to 94,000 gallons per hour, but in this case the whole shaft was free for the water-tanks, no delays in fixing a dipping-tank were necessary, and winding was practically continuous.

In using similar means for sinking through water-bearing strata under ordinary conditions, he (Mr. Morison) would anticipate considerable difficulties, under the scheme suggested, in the following respects :— (a) In providing room in the shaft for the necessary size of winding-tanks. (b) In the delay occasioned by the lowering of the dipping-tank, re-fixing it, and manipulating the auxiliary pumps, it being remembered that both tanks and pumps must of necessity be of considerable bulk. (c) In respect of the short distance mentioned (30 to 50 feet) as the lift necessary for the auxiliary pumps, and the frequent removal of the tank consequent upon the short distance. (d) In executing walling and other work required in the shafts while the water-cages and tanks occupied so much room and were passing at a high speed. (e) In the delay to winding, which would be occasioned by the slow speed at which it would be found necessary to run the water-cages into the tank to avoid dangerous shocks.

He (Mr. Morison) had some experience in winding water in sinking, under conditions which were described in a paper read by him and recorded in the *Transactions*,* and while in the case in question the method used proved eminently satisfactory and was well adapted for moderate quantities of water, he would hesitate before attempting to use a similar system for a quantity approaching 100,000 gallons an hour, as he was of opinion that the process would be neither so satisfactory nor so economical as other means of pumping, where any such quantity was anticipated. As a means of adjusting the ropes to various positions of the "dip," he (Mr. Morison) had employed double drums, one being clutched and the other fast, and by this means the ropes were adjusted with very slight delay and at frequent intervals.

Some difficulty appeared to have been experienced with the concrete coffering or tubbing, which at one period burst and liberated 200 gallons of water per minute, and it appeared to have been deemed inadvisable to repair this in consequence of a danger of bursting the tubbing elsewhere. It was also mentioned that a circular lodgment was formed behind the coffering. In employing concrete coffering, he (Mr. Morison) was of opinion that no cavity should be left between the side of the pit and the coffering, but that the cement should be run to the wall-side, so that the

* *Trans. Fed. Inst.*, vol. viii., page 118.

water-pressure was applied to the most restricted area of the walling possible. Under such conditions any fracture of the walling was less likely to occur, and if it did occur it might be safely repaired.

Mr. G. E. J. McMURTRIE (Cinderford) wrote that Mr. Galloway's paper did not necessarily show that he was in favour of or recommended such arrangements as those described, although the fact of his using them pointed in that direction. Like many others, he (Mr. McMurtrie) had had experience of winding water in cases of temporary breakdowns of the ordinary pumps. He had used a 500 gallons water-barrel, with a large circular bottom-valve for filling, and a large side flat-valve for discharging the barrel, fitted with an arrangement of levers so as to automatically discharge when pressed against a fixed projecting piece of timber shod with iron, similar to that described in the paper. In his case, two wire-rope guides were used, and although the shoot into which the water discharged was brought as close to the barrel as was considered safe, yet there was a considerable waste, which returned down the shaft, largely due to the barrel swinging back when pulled against the projecting timber. He had long contemplated adding wooden steadying-guides to prevent this swinging, and but for the fact that water-winding had very seldom to be resorted to, this addition would have been made. While he (Mr. McMurtrie) concurred with Mr. Galloway in considering water-winding advisable in cases *b*, *c*, and *e*, he would prefer to adopt small high-speed pumps in cases *a* and *d*. These pumps could be temporarily slung in the shaft during the sinking, and afterwards fixed on platforms or in small chambers at one side of the shaft. Speaking generally, *a* was the case of a new winning, and *d* of recovering an abandoned mine, while *b*, *c*, and *e* referred to a mine that was already won, and presumably landing large quantities of mineral. Thus, the circumstances of the two cases were quite different.

In sinking a new shaft, where water was expected to be found, the comparative slow speed of water-winding, and the great cost of labour, greatly handicapped water-winding as compared with pumping, apart from the great loss of time that this work must consume, unless the shaft be a large one and the Galloway stage adopted, and both water-winding and sinking carried on simultaneously. The introduction of light steel steam and delivery-pipes, owing to their small first cost, had greatly assisted the arrangement of small high-speed pumps. Moreover, when the sinking had been completed, and the water tubbed back and coal won, such pumps, in his opinion, should be retained and worked from time to

time, so that in case of accidents to the main-shaft pumps they might temporarily replace them. This arrangement would reduce the necessary expenditure on water-holds, as large holds would not then be essential. Holds were a source of considerable expense in repairs, unless arched and invert-arched, or walled, cemented, and secured with girders or railway rails.

It appeared to him that two pumps were advisable at all mines, and were absolutely essential where large quantities of water had to be pumped; and in his opinion it was advisable to retain the sinking-pumps for this purpose. In connexion with this, or where this arrangement was not considered suitable, it would be advisable to place two small pumps in the pit-bottom equal in capacity to the proposed large pumping-engine, as it was very unlikely that two pumps would break down simultaneously. The addition of a third pump, equal in power to either of the others, would entirely prevent trouble due to accidents with the pumps, especially if duplicate parts were kept of those most likely to break. Of course this arrangement would not be so economical in fuel, but against this loss must be set the saving in capital expenditure and the reduced allowances for depreciation as compared with the cost of two large pumping-plants.

If water be wound in small shafts and wire-rope guides were used, additional labour would be required to watch the dipping of the water-barrel, and to prevent it from hanging on the frame round the pit-bottom.

Where a furnace produced the ventilation, water-winding was particularly troublesome, as the drip of the water greatly interfered with the ventilation, and the steam produced greatly impeded the speedy discharge of the water-barrel.

Mr. GALLOWAY said that if Mr. Head had carefully read the papers on winding-engines which had been recently printed in the *Transactions* he would have seen that the consumption of coal used per horse-power per hour had been discussed in papers by Mr. Bramwell* and himself (Mr. Galloway),† and would have noticed that with the winding-engines therein referred to the consumption was given in pounds of steam, not in pounds of coal per horse-power per hour. If these values were transposed to pounds of coal he would find that they amounted to 10 lbs. of coal per horse-power per hour and upwards. These results appeared to be high when compared with constantly-running engines, but still, as Mr. B.

* *Trans. Fed. Inst.*, vol. xii., page 282.

† *Ibid.*, vol. xi., page 207.

Woodworth had said, winding-engines consumed large quantities of coal, and he believed that even 20 lbs. of coal per horse-power per hour were consumed in some cases.

Mr. B. WOODWORTH asked what was the indicated horse-power in comparison with the actual work?

Mr. GALLOWAY said that he had not ascertained the indicated horse-power.

A vote of thanks was accorded to Mr. Galloway for his paper.

The following "Description of Various Types of Ropeways, and Remarks as to their Proper Selection," by Mr. W. CARRINGTON, was read :—

DESCRIPTION OF VARIOUS TYPES OF ROPEWAYS, AND
REMARKS AS TO THEIR PROPER SELECTION.

By W. CARRINGTON, M. Inst. C.E.

The author, in this paper, proposes not so much to describe the various types of wire-ropeways now in use, but to consider the various purposes to which each type of ropeway is most suitable, and to point out the necessity of a selection of the type of ropeway for each variety of work which it is required to do; and for this purpose he will put forward examples of each type of ropeway, pointing out in connexion with each the special situation and circumstances under which it ought to be used, and illustrating it by some example in use which supports the views which he holds.

It must be perfectly clear that no one system of ropeway can be universally adaptable, and it is through an attempt to make it so that the discredit which fell on this system of transport in its earlier days is no doubt due.

The circumstances which should decide as to the type of ropeway to be used are many, chiefly, the character of the country which has to be traversed, the class of materials to be transported, and the manner in which such material can be packed, the motive power available, the incline to be surmounted and the spans to be crossed, the quantity to be carried per day, etc.

No engineer would attempt to use one type of boiler under all circumstances, and in the same way no engineer should attempt to use one type of ropeway for every situation and requirement.

It must be clear to any one acquainted with the working of wire ropeways that for steep inclines, long spans, heavy individual weights, etc., one type of ropeway will always present advantages over other types. The attempt to follow such an unwise course as to apply one type of ropeway in every case has thrown totally undeserved discredit on the system of wire-ropeway transport; for this type of transport can do thoroughly efficient and satisfactory work, and compete well with the ordinary ground railways of the class found in mines.

The author having studied this system of transport during the last twenty-five years or more, having been identified with its introduction, and having been acquainted with all the modifications introduced from time to time which were directed to its improvement, considers, from the point of view he takes in writing this paper, that he is qualified to make a clear, unbiased, and impartial statement to put before the members.

Ropeways have been used in one form or another for many years, but the first practical introduction of wire-ropes for the carriage of loads to any commercial extent was that made by Mr. Charles Hodgson at some quarries at Bardon Hill, near Leicester. There he erected a ropeway, which the author believes was the first ever erected on any system similar to those now in use. In his original patent, he described two systems, first that with an endless wire-rope, set in motion at a speed of about 4 miles an hour, from which the loads were hung, and with which they travel similar to the line named above, which he put up near Leicester; and the second type in which there were used two fixed ropes on which the loads hung and were moved by means of suitable wheels and one endless hauling-rope by means of which the motion was given to the carriers. This system was adopted in Germany under various names, but with the exception of a few details it was fully covered by Mr. Hodgson's patent. Up to the present time it has been most largely used on the Continent, whereas the running-rope system had been more largely adopted in this country and its colonies. For the latter countries, the author has probably constructed more lines than any other engineer on the running-rope system.

The adoption of one system by makers of wire-ropes has led largely to the use of one system under every circumstance, and from this, no doubt, had arisen the early failures in the working of wire-ropeways.

The author is certain that had the type been selected, in accordance with the requirements of each situation, and had the most efficient type been selected, the use of such a means of transport would now be many times greater than it is.

In America, a modification of the running-rope system was introduced, and for many years remained the only one in use; but more recently the fixed-rope system has been introduced, and competes with the former on equal terms.

The author, very soon after his connexion with wire-rope transport, determined not to be tied to any one system, and he has adopted five

different arrangements of wire-rope transport, from which he selects, on each occasion, the one he considers the most suitable, viz. :—

(1) The endless-running rope, as originally made by Mr. Charles Hodgson, but greatly improved in all details.

(2) An endless-rope type of ropeway, with the carriers rigidly fixed in position on the rope.

(3) The fixed-rope type, also patented by Mr. C. Hodgson, but with many improvements and alterations, differing in some details from those made in Germany.

(4) The single fixed-rope type, in which one carrier is drawn to and fro by means of an endless hauling-rope.

(5) The use of two fixed ropes, with an endless hauling-rope, in which one carrier travels in one direction while the other runs on a parallel rope in the opposite direction. This type of tramway, of course, is not new, but it has been improved and altered in many ways, and it is now a thoroughly serviceable type of tramway, capable of being used over extremely long spans, and of carrying loads up to 3 tons.

Having all these systems at command, it is easy to study the situation in which the tramway is required and the work it has to perform, and to adopt one of the five different systems named above; and this seems to be the only reasonable course to follow, and to it the author attributes the great success he has attained in this class of work.

(1) *Endless-running Rope*.—Respecting the running-rope type, the author considers that it is most suitable under the following circumstances :—Where the quantity to be carried does not exceed 400 to 500 tons per 10 hours, where the inclines do not exceed 1 in 3, and where the individual loads do not exceed 6 cwts., and also where the section of ground does not necessitate spans of greater length than 600 feet. Longer spans, steeper inclines, greater quantities, and heavier loads can be carried by this system, but not so advantageously, in the author's opinion, as another system referred to hereafter.

This type of ropeway is arranged as follows :—A driving-gear at one end, fitted with a driving-drum, varying from 6 to 10 feet in diameter, and arranged with suitable gearing for receiving the power, steam, water, or even horse-power in the case of smaller lines. At the opposite terminal, a similar wheel is placed and is provided with tightening-gear. Round these two wheels, an endless band of wire-rope is placed. Intermediately between them, the wire-rope is carried on suitable pulleys of diameter varying according to the size of the rope,

the pulleys being carried on posts of iron or timber, spaced about 200 feet apart, and of suitable height to enable the carriers to clear intervening obstacles, and also to regulate to a certain extent the general level of the line. Carriers hang from the rope and are enabled to pass the supporting pulleys by means of a curved hanger, which, pivoting in the V-shaped saddle which rests on the rope, is attached to the carrier or receptacle by means of a hook. Two types of saddle are used: in one case, the saddle is made with wood or rubber, or composition friction-blocks, held in an iron frame by means of which the necessary friction on the rope is obtained, which enables the carrier to pass with the rope up steep inclines under all circumstances. The frame which carries these friction-blocks is usually of malleable cast-iron and has wings at each end, which, as the carrier arrives at the supporting pulley, embrace the pulley-rim and pass over it. This type of frame was introduced by the author in 1874.

In the next case, the saddle is of such a form that, while resting on the rope, it passes through an enlarged groove of the supporting pulleys. In this case, the frictional connexion to the rope is frequently replaced by a mechanical arrangement which grasps the rope or by an arrangement of lug cast on to the frame or to a movable portion of it, which prevents the carrier from slipping by resting between the strands of the rope. The limit of incline workable under the first arrangement is probably about 1 in 3. In the second arrangement, a steeper incline can be worked. The lasting power of the rope, is, however, in the author's opinion, considerably reduced, as the lug prevents the rope from rotating.

In both cases, the frame which carries friction-pieces or clips is fitted with two small wheels carried on pins attached to it, which are called shunt-wheels, and are employed for removing the carrier from the rope at the terminals and at the curves, where shunt-rails are placed. These rails are held in such a position that when the carrier approaches the terminal the small wheels engage on it, and running up a slight incline, lift the friction or clip-saddle from the rope, and enable it to pass to where the loading and unloading is required to be done, or round the curve-wheels. The impetus derived from the speed of the rope, about 4 miles per hour, is sufficient to enable the carrier to clear itself automatically from the rope without difficulty. Thus, we see that the first system consists of an endless wire-rope driven by suitable gearing, with carriers hung on the rope, travelling with it either by means of friction or mechanical clips.

An example of this type of ropeway is a line of about 2 miles in length in Algeria, capable of transporting 100 tons per day of ten hours. It has one curve, about midway, in its length, and passes over some mountainous country near its upper terminal.

Another example consists of a remarkable line in Spain, where three groups of three lines each are placed between some iron-mines and a railway. The total carriage per day averages from 2,300 to 2,500 tons per ten hours. The first group of three lines was designed by the author and erected by the company for which he acted as engineer, and the remaining two groups are almost replicas of the first. Some advantages of such grouping may be mentioned, as absolute freedom from complete stoppage from breakdown, and convenience for gathering mineral from a number of scattered mines. This is well shown in the illustration of a curve made to accommodate three groups of wire lines of tramway (Fig. 1, Plate III.).

Respecting the lasting power of the ropes, which are the chief wearing parts and most expensive to renew, it may be of interest to state that on a line in Spain, carrying 300 to 350 tons per day over a length of 1 mile, one rope carried 165,000 tons, and this represented an outlay per ton per mile for rope-renewal of about $\frac{1}{4}$ d.

Including renewals of wear-and-tear and labour, but not fuel, the average cost per ton per mile for transport may be taken as varying from 3d. to 5d. per ton.

(2) *Endless-rope Type*.—The second type is similar in some respects, and is specially suitable where very steep inclines and sudden and continual changes of level have to be operated over. It is probably impossible to state the limit of incline on which this type of ropeway can work. As guard or depressing-pulleys may be placed wherever necessary without obstructing the passage of the carriers, the vertical angle of the line may change at each post. It has the driving-gear, the tightening-gear, and the endless-rope, also the pulleys, but the carrier does not rest on the rope: it is clipped to the latter by means of a steel-band which embraces it, tightened by a convenient arrangement. The position of the carriers therefore, is fixed, they are placed in position, and where the rope goes they must go. As a result, at the terminals they must go round the terminal-wheels. The driving-wheel is generally in the form of a special clip-drum, and the terminal-wheel where the tightening takes place is arranged so that the passing round of the carriers is easily effected.

Unloading can be readily done by striking a catch, causing the

bucket to capsize or open at the bottom. Loading, however, is a more complicated matter, and devices very ingenious and more or less efficient, have been devised for loading the carrier either while it passes round the driving-drum, or at a point adjacent thereto, by means of hoppers or cages going at the same speed as the carrier and operated by it.

The author has erected several lines of this type in situations where it would have been impossible, or nearly so, to use any other, and with great success. For moderate loads they prove an excellent means of transport.

(3) *Fixed-rope Type*.—The third type of ropeway is that in which two parallel fixed-ropes are used on which the carriers run drawn along by means of a hauling-rope. It should, in the author's opinion, be employed where the quantities to be transported exceed 500 tons per day, except in the case where grouped lines of the first type are suitable, and where the loads exceed 6 cwts., also where the inclines exceed 1 in 2 or 3, and spans are over 600 to 1,000 feet.

It is economical in wear-and-tear, but the first cost is great, and it does not lend itself to sudden changes in the vertical angle of the line, but where the quantities to be transported are not large the fourth and fifth type may be found superior.

The construction of this, the third type of wire-ropeway is as follows:—Two fixed ropes are stretched parallel to one another, and about 7 feet apart, being supported by posts about 300 feet apart, where special saddle-castings are provided, and being anchored at one of the terminals, and tightened at the other by suitable gear. On these fixed ropes, the carriers run, being fitted with running-heads carrying steel-grooved wheels, in which the hanger is pivoted from which the receptacle hangs. These carriers are moved at a speed of from 4 to 6 miles per hour by means of an endless hauling-rope, operated by suitable driving-gear at one end and tightening-gear at the other. The attachment of this hauling-rope to the carrier is a matter of importance, as it must be made by means of an automatic clip which will release itself on arrival at the terminal station, and at the same time will hold sufficiently tight to enable the hauling-rope to drag the carrier up the steep inclines which may occur. This is done either by forming a knot in the hauling-rope or putting a sleeve round the hauling-rope, or a suitable casting inside the hauling-rope at certain points so as to make an enlargement at that point on which the clip engages by a suitable device which prevents its escape. On arrival at the terminal, this device releases the knot or

obstacle formed in the hauling-rope, a lever attached to it being operated by a suitable striking-bar. A better arrangement however is that of a clip by means of which the hauling-rope is held simply by pressure resulting from the operation of wedges acting on inclines. This arrangement is certainly far superior to any device of knot or sleeve-attachment to the hauling-rope. and gives better results in the working of the rope. Where the inclines are only slight, simple pressure has been used by pressing two pulleys or plane surfaces together on each side of the hauling-rope. This system has answered sufficiently well where the pull on the hauling-rope is slight. In other respects this type of line has shunt-rails, supports, driving and tightening-gears in common with the first-named type.

A line of this class erected in the East, with an incline of 1 in $1\frac{1}{2}$, is worked over a distance of 1 mile, carrying about 100 tons per day



FIG. 2.

(Fig. 2.) The power generated by this falling load is absorbed at the upper terminal by a device similar to the Froude break, which has an adjustment, by means of which the speed may be regulated to a nicety, and in conjunction with a small break enables the line to be stopped with ease at any moment.

The author, in 1875, built a line in the Apennines for the carriage of timber, in which loads of 30 cwts. are transported over a length of $2\frac{1}{2}$ miles, over an average gradient of 1 in 5, there being a number of long spans, the maximum of which is over 2,000 feet between supports.

These are only examples of a number of lines which might be mentioned, but the object of the author is not to enumerate the work that he has carried out, but to mention special examples which illustrate his argument as to the selection of the proper type of tramway for each situation.

(4) *Single Fixed Ropes*.—The fourth type or single fixed rope with one carrier is most suitable for situations where moderate quantities have to be transported, and for heavy individual loads and over great spans and steep inclines it is cheaper in first cost and maintenance than the third type, and simpler to erect and to manipulate. The arrangement consists of one single fixed rope in which one carrier is employed, this carrier being drawn to and fro by suitable motive power.



FIG. 3.

The carrier hanging from the fixed rope is moved to and fro by means of an endless hauling-rope, operated by suitable driving-gear and tightening-gear, the driving-gear being arranged with reversing-gear, so that the direction in which the hauling-rope runs may be changed by the driver. The fixed rope is supported on posts at intervals of about 300 feet, and the hauling-rope is carried on pulleys fitted with guide-bars, placed in the centre of the post over which the carrier passes, the

posts being so arranged as to allow of the carriers passing through them. The return hauling-rope is carried on an outside pulley carried on an arm of the post. The hauling-rope is attached to the carrier-head by a peculiarly shaped pendant, which causes it to pass under the saddle-transom. Having used this type of tramway for some years for transporting large quantities over short distances, viz., at Nine Elms Gas-works, London, where quantities of 400 tons were transported



FIG. 4.

in 10 hours over a distance of about 450 feet, and again at a sugar-works on the Thames, where a similar quantity was transported, and in many other parts of the world, the author introduced this type for use on longer lines where smaller quantities were required to be transported.

A line at Cape Town, Cape of Good Hope, has been at work for some four or five years, transporting about 40 to 50 tons per day over a length of about 7,500 feet. The section of ground traversed is very severe, and

necessitates the use of two spans of some 1,500 feet each. This line also is arranged to carry loads up to 15 or 20 cwts., and has been at work since its erection, giving great satisfaction. Passengers have also travelled by it, but as it was not constructed for that purpose, they have always done so at their own risk; there is, however, practically no danger (Figs. 3, 4, and 5).

A similar line was erected by the author at Hong Kong, especially for the purpose of carrying workmen, and it has proved most efficient. Its



FIG. 5.

length is about 6,500 feet, and the average incline about 1 in 6. No very long spans are required, the maximum being about 600 feet. The carrier accommodates six passengers, and is an adaptation of the well-known knifeboard of an omnibus. This line passes over two water-reservoirs and several ravines. It has been at work for some seven years with complete efficiency. The motive power is steam. The only labour required is that of the engineer who controls the engine which drives the line.

(5) *Two Fixed Ropes*.—The fifth and last type is one which acts as an intermediate between the third and fourth, being most suitably used where the quantity is not sufficient to justify the use of No. 3 type or where the loads are too heavy ; also where the spans are extremely long and great simplicity of detail is desirable. It is cheaper than the third type, both as to first cost and maintenance, and requires fewer men to manipulate it.

The arrangement of this type is that of two fixed ropes stretched side by side similar to the third type. In this type only two carriers are employed, one moving forward while the other moves homeward.

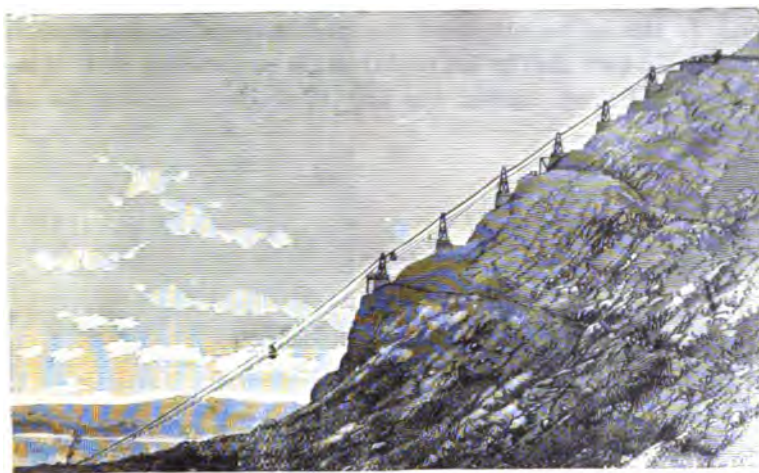


FIG. 6.

The loads are not limited, but may be up to 2 or 3 tons ; the spans also may be very great, and, under some circumstances, there may be no supports whatever. As a rule, this type of line is made self-acting on single spans or supported at points, and the load descends and draws up an empty carrier which in its turn is loaded and descends, or operated by power where the loaded carrier passes up and the empty down, and *vice versa*.

Of the former class, the line in the Alps is a good example, and the lines in the Pyrenees, where the author has erected a large number, in one case with a long span of 4,500 feet between supports.

These ropeways carry about 50 tons of mineral down and about 20 tons of stores up. The workmen habitually travel up in the carriers which run at a speed of about 30 to 40 miles per hour. The class of this type, where the loads go up hill, is well illustrated by the line at

Gibraltar (Fig. 6): here the incline is 1 to 2 and the line is 3,600 feet long, the longest span being about 900 feet. Loads of 10 to 14 cwts. are carried and intermediate landing-stages are provided. The materials transported are military stores and ammunition; one controller and one engineer work this line which can transport 80 tons per day. Authorized persons also travel to the top of the rock by this ropeway. There are many other examples which it is needless to quote.

The author, in conclusion, begs to submit that he has made out his case, and has shown that the only way to secure successful working and efficiency with wire-ropeways is to select the most suitable type in each case. To this he has attributed the great share of success which has attended the work that he has carried out in conjunction with Messrs. Bullivant & Co., of London, who have in all cases acted as his contractors.

Mr. BENNETT H. BROUGH wished to point out the inaccuracy of the statement, made in Mr. Carrington's interesting paper, to the effect that the Bardon Hill ropeway was the first ever erected on any system similar to those now in use. As a matter of fact, an old engraving, dated 1641 (reproduced in Fig. 7, Plate III.), showed an aerial ropeway with endless-rope at work in the construction of the fortifications of Dantzic in Eastern Prussia.* Another early endless-ropeway, carrying a suspended load at intervals, was described and illustrated in the remarkable book entitled *Mechanick Powers: or the Mystery of Nature and Art unveil'd*, by Messrs. V. Mandey and J. Moxon, published in London in 1696. Moreover, the ropeway, combined with a tow-line, as a means of crossing streams had been used in the Himalayas long before that date. The value of Mr. Carrington's paper would have been greatly enhanced if reference had been made to existing literature on the subject. Mr. Emerson Bainbridge's paper read before the North of England Institute of Mining and Mechanical Engineers in 1870† and Mr. J. Pohl's paper read

* The illustration is taken from Mr. B. H. Brough's Cantor Lectures on "Mine Surveying," *Journal of the Society of Arts*, 1892, vol. xl., page 828.

† *Transactions*, vol. xx., page 3.

*The Federated Institution of Mining
Transactions, 1896-97.*

To illustrate Mr. W. Cas



before the Iron and Steel Institute in 1890* contained valuable information which should not be ignored in discussing the relative merits of the various types of ropeways.

The different systems could probably be compared nowhere better than at the Bilbao iron-mines, where the most striking feature of the district was the variety of the haulage-systems employed. Experience there showed that in the Hodgson ropeways the saddles, by which the buckets were suspended from the rope, were formerly lined with india-rubber, and in rainy weather slipped to such an extent as to detract seriously from the efficiency of that system. By lining the saddles with wood and placing two toggles of steel at the extremities, this difficulty had, however, been obviated. The average daily quantity of ore carried on one ropeway was about 255 tons. On the other hand, the ropeways of the Provincial Deputation were of the Otto system, and the greatest quantity of ore brought down in one day of twelve hours was 914 tons, a remarkable quantity for a single line. Full details of these ropeways were given in Mr. William Gill's exhaustive paper read last year at the Bilbao meeting of the Iron and Steel Institute.† Undoubtedly, the most remarkable Otto ropeway was that at Garrucha in the south of Spain, the greatest span being 918 feet, the steepest gradient 1 in $2\frac{1}{2}$, and the length of the line $9\frac{3}{4}$ miles.

The preliminary survey for a ropeway was a matter that required considerable care. The terminal points of the line should, wherever possible, be so placed that the ropeway joining them should be in a straight line, for each turn not only increased the amount of construction necessary, but also the cost of working, as it necessitated the erection of a complete station at such points. At the points selected for the supports the surveyor had to determine the depth of solid ground. Frequently, too, there were other difficulties to contend with. For example, some years ago, in making the preliminary survey for an Otto ropeway in the West Indies, he (Mr. Brough) found that the work was rendered extremely complicated by the dense tropical vegetation. It was impossible to see the two ends from any point in the proposed line, and it was consequently necessary first to make a traverse and then to set the line out from the calculated co-ordinates, just as if the work were being done in a mine, a path being cut through the jungle for the line of levels.

Mr. R. E. COMMANS (London) wrote that Mr. Carrington's paper constituted a valuable addition to the somewhat limited literature on the

* *Journal*, 1890, vol. ii., page 612.

† *Journal*, 1896, vol. ii., page 36.

interesting subject of ropeways, and very clearly explained the various types of these, and the conditions which determined their employment. The importance of this means of transport was by no means sufficiently appreciated by engineers and others in this country, and the difficulties often raised by local authorities and landowners to its introduction were surprising and absurd, and no doubt in a great measure due to ignorance. Abroad, and more especially on the continent, they are undoubtedly twenty years ahead of us in the adoption of this useful and economical means of transport. A better proof of this statement could not be found than the fact that all the illustrations employed by the author in his paper are taken from lines erected by him abroad.

As a maker of ropeways of all kinds, but more especially of the well-known Otto or double-rope system, in which two fixed carrying ropes and one light endless-hauling rope are used, he (Mr. Commans) felt bound to take exception to one remark in Mr. Carrington's paper, viz :— when referring to the double-rope system, he stated that Mr. Hodgson's original patent covered this system "with the exception of a few details." These "few details" were not evident from the paper, and it was but fair to the inventor of the details of the Otto system, to add that, after careful perusal of Mr. Hodgson's published specifications, there was nothing contained in them in any way resembling the details which constituted the essential features of the Otto system, and to which undoubtedly more than to anything else, the great success of that system was due.

It could not be too strongly impressed on purchasers of ropeways that, for a ropeway to be a success, everything must be of the very best, as, like a chain, the working of the line was dependent on the strength of the weakest link, and a low first cost invariably proved in the end to be mistaken economy.

He (Mr. Commans) felt specially indebted to Mr. Carrington for this paper, in the first place, because he had in a great measure relieved him of a long outstanding obligation to read a paper on the subject before that Institution, and secondly, because there was no doubt that the more the advantages of this system of aerial transport were made known, the greater must be the demand for these lines.

Mr. W. CARRINGTON wrote that it was very curious to find that ropeways were used in 1641. They could not have been a success, he thought, or their use would not have been discontinued, and without details it was impossible to criticize the interesting woodcut (Fig. 7, Plate III.).

The description in the book entitled *Mechanick Powers*, referred to by Mr. Brough, showed that a rough type of fixed ropeway in its most primitive state had been used in very early ages, and this he had never doubted. In referring to the first ropeway at Bardon Hill, he intended to convey the meaning that it was the first example of a running-rope ropeway of the type now in use, and this he still believed it to be.

He was aware that papers had been read on the subject of wire ropeways, but he had not before seen a paper which had attempted to discuss dispassionately the various types of ropeways now in use, and to allocate to each their proper sphere. This was the object of his paper, and he trusted that he had succeeded to some extent.

He could not accept Mr. Brough's remarks as to Hodgson ropeways as being correct. Lines on this principle have worked without any difficulty for years with the use of the rubber friction-pieces on inclines of 1 in 3 and upwards, and it was only in the use of the old-fashioned saddle, used on some of the older lines at Bilbao, that any difficulty may have arisen. The want of attention to the maintenance of the saddles is the cause of much of the trouble of which Mr. Brough had heard on some of the lines at Bilbao. He could, however, point out to Mr. Brough many ropeways at work which had worked for many years past, and with which no such trouble had arisen. He knew also of several lines carrying from 350 to 400 tons per day each, and capable of maintaining this rate continuously.

No doubt one Otto fixed-rope line can carry more than one Hodgson line, but its cost is also far greater, and a group of ropeways on the Hodgson system can be made to carry as much, and certainly as economically as a single Otto line. Assurance is also obtained against total stoppage by the use of grouped lines.

He was strongly adverse to the use of the toggles of steel mentioned by Mr. Brough: he had found them to cause great wear-and-tear on the cables, and to require a considerable maintenance in themselves.

The Garrucha line was remarkable simply for its length, but in other respects it did not seem to him to present any important points.

While advocating no special type of ropeway himself, he must distinctly state that he did not accept the statement made respecting the Hodgson ropeways at Bilbao as representing the true state of the case.

He (Mr. Carrington) might point out that Mr. Hodgson's original patent comprised the use of wire ropeways worked on the endless-rope system, and also on a system which involved two fixed ropes on which the carriers were to run drawn by an endless hauling-rope, and similar

to all systems of the fixed rope type. Mr. Hodgson did not specify the use of any particular form of grip, and for all practical purposes his shunt-rail was applicable to both of his types of ropeway. While, of course, Mr. Hodgson did not patent everything which was now in use with fixed-rope tramways, he nevertheless, in his opinion, practically covered the whole scheme, leaving the special means of attaching and detaching the hauling-rope to the carrier undefined.

Respecting Mr. Commans' remarks that all the examples given in his paper referred to lines erected abroad, he might state that he had erected a number of lines at home, but that, owing to the difficulty of wayleaves, etc., they were not of so great importance as those which he had named as having been erected abroad.

The PRESIDENT moved a vote of thanks to Mr. Carrington for his paper.

Mr. N. R. GRIFFITHS seconded the motion, which was carried unanimously.

The following paper by Mr. Clement Edwards on "Railways and their Relation to the Coal Trade" was taken as read:—

RAILWAYS AND THEIR RELATION TO THE COAL TRADE.

BY MR. CLEMENT EDWARDS.

The subject of railways and their relation to the coal trade can scarcely be exaggerated in importance from the national standpoint. Mr. George Stephenson was perfectly right when he declared that the wool-sack of the House of Lords ought to give place to a coal-sack, as the true emblem of Great Britain's staple commodity. Upon a continued and cheap supply of fuel depends not only the industrial supremacy of this country, but even her capacity to prevent a rapid decline. The writer does not share in that political hysteria that has expressed itself in "Made in Germany," and which would panic-stricken seek a remedy in the reversal of the free trade policy. None the less, a bold and dispassionate examination of the facts shows unquestionably that we no longer hold that predominant lead in the world's industrial race of which hitherto we have so fondly boasted. On the contrary, we find that side by side with a small percentage of increase in the volume of our own trade, there has been a huge increase in that of Germany and other foreign countries.

It was fatuous to suppose that we should remain for any great length of time, either the carriers for Continental Europe or the workshop of the world. It was as certain as the revolving of the earth, that as soon as our industrial secrets had been wrung from us, and our commercial methods had been mastered by our neighbours, many of the nations would carry and manufacture for themselves. But while this is so as to certain nations' own requirements, it does not explain why we should have failed to hold our own position in the neutral markets, nor does it account for the great foreign invasion into our home markets. What, then, is the explanation? It is doubtless manifold. The writer does not, however, think that it is, as some allege, to be attributed to the longer hours worked by Continental workmen, for he holds with Lord Macaulay and the late Sir Benjamin Richardson, that long hours are in the end wasteful and costly, because they tend to an enormous diminution in the productive capacity of labour, out of all proportion to the extra hours worked. He feels confident that Lord Brassey was right in the deductions which he had drawn from a world-wide knowledge of definite experiments that

low wages were not economical, because wages approximate to the standard of living and the productive capacity of labour decreases in a greater proportion with the decrease in the standard of living. This view is also supported by Mr. Mulhall, the great statistical authority, who points out in his *History of Prices* that while British wages generally are 80 per cent. higher, the cost of productive power is 37 per cent. less than the average of the Continent. Any large attempt, even if it could succeed, which he doubted, to recoup our lost trade by lower wages and longer hours of work would therefore, he believed, be futile. An important factor at present, but one which he thought could only be of an ephemeral character, is the granting by the different Governments of bounties upon exported goods.

A second factor of much the same kind, and of which there are not signs wanting that the people are growing tired in several countries where bounties are paid, is the policy of selling goods for export at a distinct loss, and recouping one's self by an increase of charge to the home-consumer. But so far as this applies to our chief competitor, Germany, do not let us be too sanguine. The Germans are animated by a great and admirable national spirit, by a supreme passion for associated effort, and this may permit them to prolong what strike us as anomalies, and to suffer individually, that their nation may industrially and commercially take the first place in the world. Remember, this potent spirit, guided by a splendid intellectual enlightenment, has induced them to build up a great system of technical education, and has caused them to send hundreds of skilled industrial and commercial agents into every part of the globe to learn all that will enable them as a nation to supply the wants of the world. But for present purposes there are only two special embodiments of this spirit of associated effort to which the writer desires to direct attention. (1) The Germans have with great foresight declined to allow their mineral resources to remain in the hands of irresponsible individuals that they might cripple industry; and (2) they have nationalized practically the whole of their railways, and run them, not as great taxing-machines, but for the development and sustenance of their industry and commerce.

We now come to the immediate purpose of this paper—the discussion of railways and their relation to the coal trade. The writer will first examine to what extent the coal trade is dependent upon the railway companies. In 1892, according to the *Mineral Statistics*, prepared by the Home Office, 181,000,000 tons of coal were raised in the United

Kingdom. Of this total, we find, if we apply Mr. Mulhall's estimated proportion for 1889, that about 14,000,000 tons were consumed for colliery purposes. This leaves 167,000,000 tons, and of this net total no less than 137,000,000 tons were conveyed by the railway companies and by the canal-navigations, either actually or virtually controlled by them. That is to say, that those interested in the coal trade had to trust to the railway companies for the conveyance of about 80 per cent. of their net produce. What the amount of toll levied by the companies upon this coal was there are, unfortunately, no means of ascertaining, as no separate figures are published. All we can do is to see the total charge for all minerals, and how this works out per ton, and in relation to estimated value. In 1892, the minerals raised in the United Kingdom were 290,000,000 tons; imported, 6,000,000; total, 296,000,000. The estimated value was £95,000,000, giving an average value of 6s. 5d. per ton. According to the returns of the railway companies, 221,000,000 tons of minerals were conveyed by rail, at a total charge of £18,000,000, or a tonnage rate of 1s. 7½d. These figures show that a charge of 25 per cent. for railway rates is made on the selling price of minerals. This amount coincides with the evidence of Mr. J. S. Jeans (before the Depression of Trade Commission), and of Sir Alfred Hickman (before the Railway Rates Committee), and derived by entirely different means. This charge, then, of 25 per cent. is the tribute rendered by the community to the railway companies upon raw minerals alone.

The next point is to ascertain how British railway-charges compare with those of Germany and Belgium, where the railways are chiefly held in the hands of the State.

Table I. shows the comparative coal rates charged in this country side by side with the charges for equal distances in the two countries named, which was presented by the British Iron Trades Association to the Commission on Trade Depression in 1886.

Table II. is extracted from an analysis prepared by Sir Bernhard Samuelson for presentation to the Chambers of Commerce a few years ago.

The British Iron and Steel Trades deputation who visited Germany and Belgium reported in 1896 as follows :—

One of the largest works in Germany, situated more than 150 miles from a shipping port, could reach Antwerp by railway for 3½ marks, or 3s. 6d. per ton of finished iron or steel. Similar produce transported from works in the Midlands to London or Liverpool is charged about three times as much by the English railway companies for similar distances.

So far as Belgium is concerned, it may be sufficient to state that the works of

TABLE I.—RAILWAY CHARGES FROM EBBW VALE.

To	British. Per Ton. s. d.	German. Per Ton. s. d.	Belgian. Per Ton. s. d.
Talybont	3 0	1 7	1 11
Talylyn	3 4	1 10	2 1
Brecon	3 9	2 0	2 3
Netherton	5 11	4 4	3 11
Park Head	5 11	4 4	3 11
Woodhouse	6 11	7 11	5 3
Round Oak	6 1	4 8	4 1
Kingswinford	6 1	4 8	4 1
Brettel Lane	6 0	4 8	4 1
Corbyn Hall	6 0	4 4	3 11
Stourbridge	6 0	4 8	4 1
Cradley	6 0	4 8	4 1
Lye	6 0	4 8	4 1
Worcester	6 0	3 11	3 9
Bushey	10 9	9 6	6 0
Berkhampstead	9 6	6 10	4 10
Dunstable	10 5	8 10	5 7
Bletchley	9 3	6 5	4 8
Banbury	8 9	5 11	4 6

TABLE II.—RAILWAY CHARGES FROM BESTWOOD.

To	British. Per Ton. per Mile. d.	German. Per Ton. per Mile. d.	Belgian. Per Ton. per Mile. d.
Boston—			
Home	1·21	0·69	0·75
Export	0·63	*	0·34
Lynn—			
Home	0·79	0·59	0·59
Export	0·50	*	0·31
Sleaford	1·50	0·77	0·87
Grantham	1·51	0·89	0·96
London	0·52	0·52	0·36

* No German port so near collieries.

Couillet can transport their finished iron and steel to Antwerp—a distance of 70 miles—for 3s., or an average of 0·51d. per ton per mile. As against this low export rate, compare the following rates for export from Staffordshire:—

TABLE III.—RAILWAY RATES FROM STAFFORDSHIRE.

To	Distance. Miles.	Parcels of 4 to 10 Tons. Rate per Ton. s. d.	Rate per Ton per Mile. d.	Parcels of 10 Tons and Upwards. Rate per Ton. s. d.	Rate per Ton per Mile. d.
Bristol	94	8 4	1·06	8 4	1·06
Fleetwood	126	14 2	1·35	14 2	1·35
Gloucester	56½	6 8	1·415	6 8	1·415
Hull	134	14 4	1·283	12 6	1·119
Liverpool	97½	10 0	1·230	10 0	1·230
London	113	15 0	1·502	12 6	1·327

The difference here is most marked. It will be observed that, if we take the cost of transport from the Staffordshire district to London, an average distance of 113 miles, the ton-mile rate for 4 to 10 tons parcels is 1·502d., or about three times the average ton-mile rates of Belgium and Germany for export trade.

Mr. J. S. Jeans, secretary of the British Iron Trade Association, stated that the average British rates were for :—

Iron ore	...	...	...	58	per cent.	higher than	France.
"	...	...	...	87	"	"	Germany.
"	...	...	...	87	"	"	Luxemburg.
"	...	...	...	82	"	"	general average of foreign countries.
Pig-iron, works to ports...				40	"	"	France.
"	...	...	...	43	"	"	Germany.
"	...	...	...	102	"	"	Belgium.
Works to inland markets				68	"	"	France.
Finished iron and steel, works to ports	...	...	...	79	"	"	France.
"	...	...	...	96	"	"	Germany.
"	...	...	...	23	"	"	Belgium.
To inland markets	...	...	...	120	"	"	France.
"	...	...	...	115	"	"	Germany.
"	...	...	...	30	"	"	Belgium.

The Mining Association of Great Britain stated that :—

The heavy trades of coal and iron are also unduly burdened by the high rates and tolls charged by the railway companies of the kingdom ; the rates in question are much higher than those charged in other countries, notably higher than in the United States of America and the Continent of Europe, and in some instances (e.g., the rate to London) the charges were raised in 1873 on the specific ground that coal and iron were so dear. They have not been reduced, though, as everyone knows, the prices of iron have fallen to a figure before unknown, and the prices of coal are lower, relatively to the cost of production, than at any previous time. The railway companies are slowly but surely killing the trade of this country by their high charges, and by the preference given to foreign competitors.

The writer will now proceed to discuss the question of railway-transit from the standpoint of the prospective exhaustion of our coal-supply. He does so with a great deal of timidity. In the first place, he knows little about the subject of mining, and, in the second place, even if he did, the question of coal-exhaustion is so problematical, being subject to so many varying and almost incalculable factors, that he hesitates to treat of its possible relations to a definite and a pressing problem. He must, therefore, crave particular indulgence in this part of his paper. The coal-resources of the world are apparently so huge and so incalculable that, if we had reached that desirable stage of the "brotherhood of man, the federation of the world," as would enable us to treat of

the world as a single unit, we might very easily afford to dismiss the subject of possible exhaustion as perfectly futile. But, unfortunately, we cannot do so. We have to remember that each nation constitutes a unit, and that between them there is the keenest rivalry and the most strenuous competition. As an eminent writer has rightly said, "we can never hope to feed our furnaces and work our looms by the aid of fuel from other parts of the world." Consequently, we are compelled to look at the prospects of our own coal-supply in relation to those of other nations. What are the facts?

There have been three notable estimates of the available coal-supply. Prof. Hull estimated it in 1860 at about 70,000,000,000 tons, but that quantity was a net supply after (1) making deductions for waste, and (2) not including seams less than 24 inches in thickness, nor, as he said (3), "those supplies under certain districts overspread by formations newer than the Carboniferous." The Coal Commission of 1865 estimated the gross available supply, including the last two classes omitted by Prof. Hull. Their estimate placed the supply at 146,000,000,000 tons, calculated as follows :—

	Available within a Depth of 4,000 Feet. Tons.		Non-available, Depths exceeding 4,000 Feet. Tons.	
Exposed coal-fields	...	90,206,240,387	...	7,320,840,722
Unexposed	...	56,248,000,000	...	41,144,300,400

Mr. Mulhall, who appears to have ignored the prospective capacity of the unexposed beds, estimates the available supply at 90,000,000,000 tons. There seems to be little or no difference of opinion among recognized authorities that 4,000 feet represents the maximum depth from which it is physically possible to get coal, but there is some difference as to whether it is reasonably practicable to work even to that depth, owing to the possible increase of temperature. The temperature at a depth of 4,000 feet had been stated by Prof. Hull in the following form :—

	Degr. Fahr.			
Invariable temperature of surface	...	...	...	50.50
Increase due to depth	...	...	...	56.42
Increase due to density of air...	...	...	...	13.16
Resulting temperature at a depth of 4,000 feet	...	...	...	120.08

Assuming, however, that down to a depth of 4,000 feet, which is some 1,300 feet, the writer believes, below the present deepest coal-mine, it is physically possible to mine coal, the very serious question of commercial possibility comes in.

Much may be done to promote economical results by working larger areas of mineral from the same twin-shafts, by forming consolidated

companies for economical drainage, by perfecting machinery, and organizing labour to contend with the growing cost. But increased areas and distances of working, though comparatively diminishing the capital expense of the shafts and works above ground, will increase the current expenses of drainage, ventilation, and general maintenance.

In a word, the law of diminishing return comes into active operation the deeper you go in your mining—with the grave difference that, not only will there be a diminished annual return per expenditure of effort, but a final exhaustion. Thus Prof. John Stuart Mill said :—

Mining industry, for example, usually yields an increase of produce at a more than proportional increase of expense. It does worse, for even its customary annual produce requires to be extracted by a greater expenditure of labour and capital. As a mine does not reproduce the coal or ore taken from it, not only are all mines at last exhausted, but even when they as yet show no signs of exhaustion, they must be worked at a continually increasing cost. Shafts must be sunk deeper, galleries driven farther, greater power applied to keep them clear of water, the produce must be lifted from a greater depth or conveyed a greater distance. The law of diminishing return applies, therefore, to mining in a still more unqualified sense than to agriculture.

Prof. Marshall also said :—

It is true that we find continually increasing difficulty in obtaining a further supply of minerals (except in so far as we obtain increased power of nature's stores through improvements in the arts of mining and through better knowledge of the contents of the earth's crust); and there is no doubt that, other things being equal, the continued application of capital and labour to mines will result in a diminishing yield.

But as Prof. Jevons said :—

Be the difficulties what they may, we should have ingenuity and energy enough to overcome them, were the question one of a simple absolute amount of difficulty. But in reality we must consider our mines not by themselves, but in comparison with those of other countries.

Mr. Mulhall made the following estimate for 1889 of the estimated available supply and annual production and consumption of coal :—

	Production. Tons.	Consumption. Tons.	Estimated Supply.	
			Area. Square Miles.	Tons.
Great Britain ...	177,000,000	148,000,000	9,000	90,000,000,000
France ...	24,600,000	34,600,000	1,800	—
Germany ...	84,900,000	75,000,000	—	100,000,000,000
United States of				
America ...	142,000,000	143,000,000	94,000	—
Belgium ...	19,800,000	14,300,000	1,400	—

Thus, we find, if the present rate of consumption is maintained, that both the United States of America and Germany, our chief competitors, have a much longer supply than we possess. But how far the actual

and the relative rate of consumption may increase or decrease in these different countries it is impossible for us to tell. All we can do is to measure possibilities by the present rate of consumption. Taking Great Britain alone, Prof. Jevons had made the calculation that we had an available supply for about 100 years only. This calculation, made in 1866, was based upon the assumption that the average rate of increase in consumption would be $3\frac{1}{2}$ per cent. per year. The excellent chart in the *Mineral Statistics*, 1895, shows that this assumption agrees with the actual increase up to 1875, but since that year the actual increase has fallen short of Prof. Jevons' calculation. The difference for 1895 amounts to 80,000,000 tons, so that the date of final exhaustion is happily less imminent than we had been led to expect.

An important question is that of the relative cost of mining in different countries, but unfortunately the writer has not been able to obtain any figures upon the subject. It is quite obvious, however, from Mr. Mulhall's statistics, that in the primary cost of fuel we are at a great disadvantage as compared with Germany. Prof. Mulhall's table of pit-mouth prices is as follows :—

Period.	Pence per Ton.					
	Great Britain.	France.	Belgium.	Austria.	Germany.	United States of America.
1871-75 ...	87	190	168	78	108	114
1876-80 ...	88	120	102	66	66	80
1881-85 ..	72	108	90	60	63	100

And this grave disadvantage is likely to increase the deeper we go for our coal. Again quoting Prof. Jevons :—

When the general depth of coal-workings has increased to 2,000 feet, little or no coal will be sold for less than 10s. per ton. Our iron and general manufacturing industries will have to contend with a nearly double cost of fuel. And when with the growth of our trade and the course of time, our mines inevitably reach a depth of 3,000 or 4,000 feet, the increasing cost of fuel will be an incalculable obstacle to our further progress.

The optimists may of course say that we can find a compensation in the development of other motive power, but the writer thinks that there is little consolation to be derived in this reflection, when such alternative power, being open to the world, will give us no relative advantage.

Prof. Jevons also said :—

For let us remember that we are dependent on the comparative cheapness of fuel and motive power. Now, comparative cheapness of fuel cannot be procured or retained by inventions and modes of economy which are as open to our commercial competitors as to ourselves, which have in many cases been introduced by them, and are more readily adopted by versatile foreigners than by English manufacturers bound by custom and routine. Even our superior capital will not avail us against dear fuel, because nothing more readily flows abroad in search of profitable employment than capital.

To summarize, then, we find that our coal-supply is nearly certain to give out before that of our chief competitors, but that long before the period of final exhaustion has been reached, the cost of mining will have become much higher than in the case of competing nations. Now, under these circumstances, the problem that we shall have to set ourselves to solve will be this : concurrently with the necessary increase in the cost of mining, can we recoup sufficient from unnecessary margins of expenditure to allow coal to be supplied at a price which will enable us as a nation to hold our own against foreign competitors ? If we cannot, then our supremacy is doomed. There is a considerable margin to be secured as a nation by putting railway rates upon a just basis from the national standpoint, so that the extra cost of mining may be largely compensated by the much cheaper cost of carriage.

This, then, brings the writer to the final question : Are we likely to get this satisfactory rearrangement of rates out of the present railway companies ? For sixty years, there has been a fight between the traders and the railway monopolists, and the traders have been worsted continually. Since 1838, nine Royal Commissions or Select Committees have sat to revise railway rates, and yet to-day relatively the position is worse than ever. The writer believes that the remedy is to be found in nationalization of the railways, for he holds with Prof. Mill that :—

The charge made for services which cannot be dispensed with is in substance quite as much compulsory taxation as if imposed by law. A road, a canal, or a railway, these are always in a great degree practical monopolies, and a government which concedes such a monopoly unreservedly to a private company does much the same thing as if it allowed an individual or an association to levy any tax they chose, for their own benefit, on all the malt produced in the country, or on all the cotton imported into it.

In advocating the nationalization of railways, the writer only does so after the most careful enquiry into the subject. He finds that there are wastes incident to our system ; and we have all the disadvantages of competition without any of its advantages. The railways of the country are one combination, and in rates and facilities there is no competition. The definite waste of the system has been estimated at more than £10,000,000 a year. This estimate takes no account of many possible economies that might be effected under single management. Then it is found that foreign goods are now carried invariably at a cheaper rate than British-made, because it is urged that, if they were not, they might be carried by ships and over other routes.

On the other hand, the writer finds that the acquisition by the state of the railways has been attended by improved services, cheaper rates, and very great advantages to the community. These advantages are especially obtained in Germany, Belgium, Austria, Holland, India, and Australia.

And to prove that they may be made to pay, we may quote from a report on the German railways, where, as the writer has already shown, much cheaper rates prevail than here.

The immense financial importance of the state railways to the kingdom of Prussia is shown by the figures contained in the budget for 1896-97 just published. The gross receipts from state railways in Prussia, according to the budget, is 1,027,173,000 marks (£50,351,817), or more than half the net revenue of the state from all sources, the latter being 1,941,000,000 marks (£95,147,059). The net earnings of the Prussian state railways after the payment of 223,700,000 marks (£10,965,686) interest on the working-capital and for sinking-fund is 214,500,000 marks (£10,514,705), which will be turned into the treasury for the use of the state. This sum is 46 per cent. of the net receipts of Prussia, and larger than the income derived from taxes of all kinds, which is 181,300,000 marks (£8,887,255), only 39 per cent. of the total state revenues.

With regard to the financial aspects of acquisition there is an act of parliament, introduced by Mr. W. E. Gladstone, and passed in 1844, by which the terms are more or less defined for us. This act, which is usually spoken of as the "Cheap Trains Act," provides that the government can "at any time after the expiration of the said 21 years from 1844, purchase any such railway, with all its hereditaments, stock and appurtenances, in the name and on behalf of Her Majesty, upon giving to the said company three calendar months' notice in writing of their intention, and upon payment of a sum equal to 25 years' purchase of the said annual divisible profits, estimated on the average of the three then next preceding years." We may see at a glance approximately what this would mean. Roughly speaking, the profits upon our railways are 4 per cent., yielding, in 1895, £39,000,000. This amount, at 25 years' purchase, shows that £975,000,000 will be the cost of acquisition. But while the railways yield 4 per cent. profit, it is not too sanguine an estimate to say that the government will not need to pay more than $2\frac{1}{2}$ per cent. This diminished interest shows that an annual payment of £23,000,000 will be sufficient, as against the present profits of £39,000,000, resulting in a clear profit of £16,000,000 per annum on the present basis, and without allowing for any economies resulting from single management and the prevention of wastages under the present system. These wastages have been placed by an eminent authority at a minimum of £10,000,000 a year, which, added to the profit of

£16,000,000, after paying interest, leaves a sum of about £26,000,000, or say only £20,000,000 per annum. But let us glance a little further: the receipts from passenger traffic amount to £36,500,000, goods traffic, £43,500,000, the total traffic being £80,000,000. Consequently, if no immediate provision were made for redemption of the purchase money, the saving of £20,000,000 per annum would admit of goods rates being reduced by 45 per cent. Presumably, however, the weight of judgment, as well as the sense of fairness, would lean to dividing this surplus equally between the goods and passenger customers and the employes, and some provision towards redemption, remembering always, however, that up to a point the cheapening of goods rates and passenger fares will tend to the increase of traffic in a degree that cannot be calculated. As to the method of purchase, the plan adopted in Germany seems the wisest and best, in which the substitution of state scrip obviated the need of the government raising the purchase money.

So convinced is the writer of the enormous possibilities of common good attending the nationalization of our railway system, that, in conclusion, he would fain express the hope that The Federated Institution of Mining Engineers may do something to help it forward.

The PRESIDENT proposed a vote of thanks to Mr. Edwards for his paper and it was agreed to.

The PRESIDENT proposed that a vote of thanks be accorded to Prof. Boyd-Dawkins for the papers which he had prepared on the "Dover Boring" and the "Salt-field of the Isle of Man," and which he had proposed to deliver that morning at Owens College.

The motion was agreed to.

DISCUSSION ON MR. W. GALLOWAY'S PAPER ON "SECONDARY HAULAGE."*

Mr. H. F. BULMAN (Byermoor) wrote that, in comparing different systems of secondary haulage, the number and position of the working-places relatively to the collecting-siding, and the output from each working-place, were matters that required attention. It would add interest to Mr. Galloway's paper if he would describe the situation at Llanbradach colliery in these respects.

* *Trans. Fed. Inst.*, vol. xii., page 257.

The accompanying sketch (Fig. 1) showed the present position of the working-places, with the roads from them to the collecting-siding, in a district of pillar-working on the bord-and-pillar system at a Durham colliery, where the tubs were conveyed between the working-places and the collecting-siding by boys driving ponies, and it might be taken as a typical example. Each working-place, occupied by one hewer at a time, was denoted by a number. On an average 28 tubs, containing about 8 cwts. each of coal, were filled in each working-place

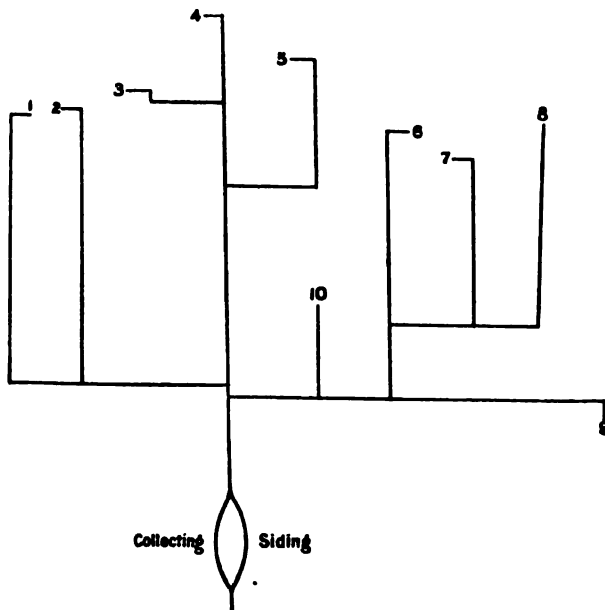


FIG. 1.—SKETCH SHOWING WORKING-PLACES AND THE COLLECTING-SIDING IN PILLAR-WORKINGS WITH PONY-PUTTING. Scale, 3 Chains to 1 Inch.

and conveyed to the collecting-siding in each day of ten hours' work. Five putters with five ponies were employed, and, allowing for time spent in walking from and to the shaft, and time for food, the time devoted to the work was not more than $8\frac{1}{2}$ hours. Considering the number of branches, and the number of right-angled turns which the tubs had to pass, and the necessarily, in many cases, rough condition of the road owing to natural unevenness in the floor, and sometimes, in pillar-working, to the heaving of the floor where the strata below the seam were soft and wet, mechanical rope-haulage did not seem to be well suited to such circumstances. Pony-putting, in comparison with mechanical haulage, had the advantage of being more readily adaptable to varying circumstances.

The output from each place varied from day to day, and the tubs must be removed as quickly as they were filled by the hewers or their work was impeded. A putter should go at once where he was wanted, and no precise order in the removal of the tubs could well be carried out.

In this instance, the boys were paid 11½d. a score (20) of tubs plus the current percentage (15 per cent). The average distance was 195 yards. In one fortnight 2,444 tubs of coal, containing an average weight of 8 cwts. 0 qrs. 7 lbs. each, equal to 985 tons, and 458 tubs of fire-clay containing an average weight of 10 cwts. 0 qrs. 18 lbs. each, equal to 233 tons were thus conveyed, and the wages paid to the 5 putters amounted to £6 19s. 2d., or adding 15 per cent., £1 0s. 10d., a total of £8.

Ponies and horses being usually kept together at collieries, it was difficult to obtain exact figures for the cost of ponies alone. But if three ponies below 12 hands in height, such as were commonly used for pony-putting, were equivalent in cost of keep to two horses averaging 15½ hands high, actual figures taken over four years on a stable of 25 ponies and 22 horses give the average cost as 9s. 4d. per pony per week, including food, attendance, saddlery, and shoeing. The cost of five ponies for a fortnight would thus be £4 18s. 4d.

The cost, therefore, for 1,218 tons led over an average distance of 195 yards was—

Pony-putters' wages	...	...	£8	0	0	or 1·576d. per ton.
Cost of ponies, etc.	...	...	4	13	4	„ 0·919d. „
Totals	...	...	£12	13	4	„ 2·495d. „

Similar costs taken over nine similar districts during a period of three months, the distances varying from 180 to 280 yards for a quantity of 29,337 tons, gave almost the same result, viz. :

Putters wages'	...	...	£179	16	3	or 1·471d. per ton.
Cost of ponies, etc.	...	...	123	16	0	„ 1·012d. „
Totals	...	...	£303	12	3	„ 2·483d. „

It seemed, therefore, that 2½d. a ton, including 1d. a ton for the cost of ponies, might be considered as the normal cost of pony-putting.

Expanding this to the ton-mile standard, and comparing it with Mr. Galloway's figures, there was no doubt that Mr. Galloway's costs showed a considerable economy in favour of mechanical haulage as adopted at Llanbradach colliery. Whether this system could be adapted to the bord-and-pillar method of working as carried out in Durham and Northumberland, to convey the tubs between the working-places and the

collecting-siding, in as efficient a manner as was now done by pony-putting, was very doubtful, and it might be an additional reason for adopting the longwall or double-stall methods of working.

On the authority of Mr. Ernest Boissier, Mr. Galloway took five years as the average life of a horse employed underground, but the experience of the writer in Durham and Northumberland led him to put it at about double this period, or say ten years. There were ponies still at work which had been working regularly underground for twenty years. Much no doubt depended on the conditions under which they worked, and on the care and attention bestowed on them.

Mr. GEORGE J. BINNS (Netherseal) wrote that the system of haulage which was termed by Mr. Galloway secondary, but to which he thought the term auxiliary should preferably be applied, was one which had engaged his attention for some years, and it was only in old roads where, owing to long existing conditions, mechanical means could not be adopted, and in new workings where various causes had prevented its application, that horse-power was now used. Ropes were run along the coal-face and down old gates where stowage room existed, perhaps in the latter case only a dozen or twenty trams a week being dealt with; empties were drawn, for the supply of a haulage-plane, from a point to which they ran by gravity; stone-heads were kept clear of dirt by means of small engines which ran the tub into the face, and each of these, under the recent definition of the Home Secretary, now became a "main haulage-road." It was true that at the coal-face the removal of the rails by only one "web" of coal changed the character of the road, and it ceased to come within that all-embracing definition, but in the other cases this character must remain for ever unchanged, and even the substitution of horse-haulage, with all its attendant dust and danger, could never remove from a place where a rope had once run, its disabilities under the recent order. It might be in one case that the tub was hauled singly, on a wet floor, at a speed not exceeding 2 or 3 miles an hour, with the very best modern appliances; and that in the other, many horses, each with a train of 20 trams in either direction, were succeeding each other at short intervals on a level (which need not be a "main intake") covered with dust and foecal matter: one was a "main haulage-road" and must for ever remain so, and the other was not. This definition had a most important bearing on the system described by Mr. Galloway, as the adoption of a safe, reliable, and modern method of transport imposed restrictions upon a mine which were not shared by less enterprising (or it might be differently

circumstanced) owners, restrictions which were at the present moment absolutely insuperable.

He (Mr. Binns) agreed cordially with Mr. Galloway as to the great advantages of mechanical auxiliary haulage, and especially with the opinion expressed as to the advisability of employing compressed air.* There were, however, some details in connexion with the subject which were not dealt with either in the original paper or the discussion, and he therefore proposed shortly to communicate them to one of the Federated Institutes.

DISCUSSION ON MR. W. D. WIGHT'S PAPER ON "AUTOMATIC VARIABLE EXPANSION-GEAR APPLIED TO BALANCED SLIDE-VALVE WINDING-ENGINES."†

Mr. A. BEVER (Dewsbury) wrote that the statement in the paper to the effect that advantages were possessed by an ordinary slide-valve over the Cornish valve in admitting of the use of lead and compression seemed to show that Mr. W. D. Wight was under the impression that it was impossible to work Cornish valves with lead and compression. Mr. Hargreave Walters in his paper on "The Lead and Lap of Winding and other Engines," ‡ also referred to the same subject and seemed to be of the same opinion.

There was not the slightest difficulty in working Cornish or drop valves with lead or compression, and they could be made to cut off the steam at any desirable point with the same ease as a slide-valve. His firm had made a large number of winding-engines, both with slide-valves and with Cornish valves, and they invariably set the valve-gear so that the admission-valves had lead and the exhaust-valves compression. This arrangement was of very great advantage in easy running, and also in economy of steam, particularly when running at a high speed. The exhaust-valves were also set so as to open when the pistons had made from 90 to 95 per cent. of the stroke, and thus allowed a considerable portion of the exhaust-steam to escape before the commencement of the return-stroke and prevented the heavy back pressures so frequently met with in winding-engines.

* *Trans. Fed. Inst.*, vol. xii., page 277.

† *Ibid.*, page 279.

‡ *Ibid.*, vol. xi., page 64.

DISCUSSION ON PROF. DE LAUNAY'S "GEOLOGICAL DESCRIPTION OF THE GOLD-MINES OF THE TRANSVAAL." *

Mr. A. R. SAWYER (Johannesburg) wrote that Mr. L. de Launay stated that Mr. Draper "has noted below the gold-bearing conglomerates, alternating beds of quartzites and shales," etc. The following appeared in the *Transactions of the Geological Society of South Africa*.† In his reply to Mr. Draper, he (Mr. Sawyer) stated that :—

Mr. Draper mentions the presence of granite at Vredefort and at the Half-Way House. These are the only two points at which granite, gneissoid granite, or other acid igneous rocks have so far been, if not discovered, at all events described, to my knowledge. I wish to point to a third place close to the Rand, where granite and gneiss occur in abundance, namely, about 13 miles due east of Heidelberg. There, the mode of occurrence of the clay-slate series is exactly similar to that north of the Rand. The same sharp and high escarpment of white quartzite with a north-and-south trend, turning to the north-east and dipping at right angles of from 30 degs. to 50 degs. to the west and north-west. This thick bed of quartzite rests directly upon masses of gneiss and granite, which extend for a considerable distance eastwards, where they are lost beneath grits and breccias belonging to the Coal-measures of this country, and lying nearly horizontal. This is another proof that the dolomitic limestone does not lie beneath the clay-slate series, at all events here. The clay-slate series consists here, just as it does north of Johannesburg, of alternating beds of quartzites and slates. Some of these slates are highly ferruginous. One bed in particular consists of alternate bands of magnetite and sugary quartz, presenting most fantastic contortions, and is probably the identical one named by Mr. Draper, an index to the main reef. It resembles numerous magnetite-rocks, which I have noticed in Mashonaland. This bed is the identical one which I have followed from the Hospital Hill to Krugersdorp, past Hartebeestfontein and Blaauwbank, where it disappears beneath the black reef and Gatsrand series, with a south-west trend.

Further, Prof. de Launay stated that "Mr. Goldmann puts on record at Vereeniging, 30 miles or so south of Johannesburg, coal-beds unconformably overlying the dolomite," etc. On the same occasion, he (Mr. Sawyer) made the following remarks, which appeared in the *Transactions of the North Staffordshire Institute of Mining and Mechanical Engineers* :—"I was fortunate enough to come across two fossils of *Lepidodendron* and one of *Favularia*" in the coal-beds at Vereeniging in 1889, these I submitted to Prof. Williamson, who verified them as such.‡

* *Trans. Fed. Inst.*, vol. xi., page 378. † Vol. i. No. 1.

‡ 1889, vol. x., page 85.

DISCUSSION ON MR. DONALD M. D. STUART'S PAPER ON
"THE PHENOMENA OF COLLIERY EXPLOSIONS."*

Mr. W. C. BLACKETT (Durham) wrote that he had read with some disappointment Mr. Stuart's rejoinder to the remarks made in the various criticisms on his (Mr. Stuart's) interesting paper, because he had expected that many of his (Mr. Blackett's) contentions would have received careful consideration. Nothing in Mr. Stuart's rejoinder had controverted the arguments used by him (Mr. Blackett) and many of these were necessarily fatal to Mr. Stuart's theory, and it would be tautology to refer again to all the points raised.

For instance, Mr. Stuart reasserted that "the absence of mechanical force between the explosions was a fact of observation."† Now, this fact he (Mr. Blackett) again absolutely denied, and despite Mr. Stuart's claim to having used "exact methods of observation and measurement," which "could not be questioned," he (Mr. Blackett) after "equally exhaustive investigations," was bound to conclude that Mr. Stuart's methods of observation had failed in arriving at correct deductions.‡

Mr. Stuart's "methods of observation" have certainly been wanting in reading his (Mr. Blackett's) portion of the discussion, or he would not have said that "Mr. Blackett suggested that this mutilation [of bodies, etc.] was produced by a current of air at a speed of 100 miles per hour."§ What he (Mr. Blackett) had really said was that if a speed of 100 miles per hour was "imparted to a man's body"|| it would account for such injuries. Did Mr. Stuart really dispute this opinion? Had Mr. Stuart read this paragraph correctly, all his erroneous calculations as to the pressure of air would have been unnecessary. The human body did not usually sustain a pressure of 14·7 lbs. on the square inch, because it was not called upon to do so, the pressures being in equilibrium. For Mr. Stuart to compare the effect of a balanced statical pressure with an unbalanced dynamical pressure was something like trying to multiply eggs by pennies, and suggested a slight relapse from that laboratory-like state of precise observation which Mr. Stuart had pronounced to be so desirable. Nevertheless, if Mr. Stuart could peruse the literature on great storms and tornadoes, he would find what moving wind could do. Take

* *Trans. Fed. Inst.*, vol. xii., page 371.

† *Ibid.*, page 404.

‡ *Ibid.*, page 403.

§ *Ibid.*, page 405.

|| *Ibid.*, page 396.

the cyclones of the Mississippi valley, uprooting from their path trees 3 or 4 feet in diameter, with houses overturned and smashed to pieces. Or take the storm in Guadaloupe in 1828, where tiles were blown through thick doors ; or that at Calcutta in 1823, where a piece of bamboo was driven through a wall 5 feet in thickness. Let us even take Mr. Stuart's figure of "0·34 lb. per square inch" * applied to a man, whose lateral area was, say, 7 square feet. The pressure would equal about 336 lbs., or the weight of two 12 stones men ; and this pressure, with the velocity involved, so far as the "teachings of mechanics" were concerned, was likely to do under certain circumstances all the injuries to men ever seen, and, paraphrasing the late Mr. George Stephenson, it would be "very awkward" for Mr. Stuart or any other man if he were so unfortunate as to encounter such a kinetic force.

Mr. JEREMIAH HEAD (London) moved that the best thanks of the members be given to the committee of the Midland Institute of Mining Engineers for making arrangements for that meeting ; to the owners of the various works and collieries opened to the inspection of the members ; and to the Manchester Geological Society, the Manchester Conservative Club, the Manchester Reform Club, and the Arts Club.

The PRESIDENT seconded the vote which was carried unanimously.

Mr. A. SOPWITH (Cannock) moved a vote of thanks to the President for his services in the chair, which was accorded, and the meeting closed.

The following notes record some of the features of interest seen by visitors to works and collieries, which were, by kind permission of the owners, open for inspection during the course of the meeting on February 17th, 18th, and 19th, 1897 :—

* *Trans. Fed. Inst.*, vol. xii., page 405.

MANCHESTER COURIER AND EVENING MAIL.

Members visited the printing works of the *Manchester Courier* and *Manchester Evening Mail*, and were shown the various details of the production of the fourth edition of the *Evening Mail*, including the operating of the Linotype machine, and printing, folding, despatching, etc., of the papers.

LANCASHIRE AND YORKSHIRE RAILWAY COMPANY, ENGINEERING WORKS, HORWICH.

The workshops are built between the Chorley New Road at Horwich and Red Moss, and are about 1 mile distant, in a northerly direction, from the Blackrod station, upon the main line between Manchester and Fleetwood. A short fork line has been made, giving direct access to and from Manchester without passing through the Blackrod station.

The building of these works was commenced in 1886. They were erected for the purpose of repairing and renewing the whole of the locomotive stock, and carrying out the mechanical engineering work of the railway. The land enclosed for the works includes 96 acres, and the covered area of workshops is $16\frac{1}{2}$ acres, comprising offices, general stores (with gallery), boiler-shop, smithy, forge, foundries, erecting and repairing-shops, etc.

There are $6\frac{1}{2}$ miles of tramways of 18 inches gauge, and a number of small locomotive engines are used for the carriage of materials from the stores, and of work to and from the various departments of the works.

MESSRS. W. H. BAILEY & CO., LIMITED, ALBION WORKS, SALFORD.

The members were shown Davidson direct-acting steam-pumps for pumping under ordinary conditions, boiler-feeding, Bessemer plant purposes, cotton-pressing, mine-pumping, and hydraulic work generally—from heads of 100 feet to pressures equivalent to 4 tons per square inch.

The Denaby straight-line sinking-pump was also shown. This type of pump was designed by Messrs. W. H. Bailey & Company,

Limited, for the sinking of two large shafts over 600 feet in depth by the Denaby Main Colliery Company, at Cadeby, near Doncaster. The pump occupies very little space, and, owing to its light weight and the Davidson positive valve-motion, it works when suspended in chains or steel ropes. As the sinking proceeds, extra lengths of pipes are added at the top of the shaft, and a telescopic suction-pipe enables the sinking to proceed for a depth of 9 feet without necessitating the lowering of the pump. It can be fixed permanently in the shaft after the sinking is completed. Eight of these pumps were supplied to the Denaby Main colliery.* The aquathruster pump was also shown; it is an improved pump of the pulsating type.

Another speciality was the water-motor pumping-engine, for pumping against great heads by means of low pressure. Water-motors, for hauling purposes, and air-compressing machinery are also amongst the manufactures of this firm.

Special departments are devoted to the manufacture of various kinds of recording apparatus, including mine-ventilating recorders, water-level recorders, steam, water, and blast-pressure recorders, speed indicators, winding indicators, etc.

In the testing-machinery department are made machines for testing iron and steel, wire, cement, canvas, and materials of construction generally, together with oil-testers, etc.

**MESSRS. ASHTON BROTHERS & COMPANY, LIMITED,
CARRFIELD SPINNING AND WEAVING MILLS, HYDE.**

The machinery in the older mills is driven by compound engines, with steam at a pressure of 80 lbs. per square inch, and in the newer mills by compound engines of 1,000 horse-power of the Corliss type, and two sets of triple-expansion horizontal engines, each of 500 horse-power, with steam at a pressure of 150 lbs. per square inch. Rope-driving is applied on an extensive scale.

The steel boilers are 30 feet long by 8 feet in diameter, carrying a pressure of 150 lbs. per square inch. The newer mills are lighted by about 1,000 electric incandescent lamps. There are about 120,000 spindles for spinning the yarn for 2,335 looms, and 1,650 workpeople are employed. The average production per week is 567,000 yards of calico, weighing about 130,000 lbs. or 58 tons.

* *Trans. Fed. Inst.*, vol. iii., page 513.

**HYDE LANE COLLIERY CO., LTD., HYDE COLLIERY,
MANCHESTER.**

The Hyde Lane colliery is situated in Hyde, on the main road between Hyde and Manchester, being about $6\frac{1}{2}$ miles from the latter place. The colliery, one of the oldest in the district, has been worked for a long series of years; it is now being worked by the Hyde Lane Colliery Company, Limited.

The colliery consists of two shafts, the downcast and winding-shaft being 822 feet in depth, and the upcast shaft 660 feet in depth. The shafts were first sunk to work the black mine, but have been further sunk through the two feet mine to the peacock mine.

The black mine is the most valuable coal-seam in the district, as it affords an excellent gas and house coal; but until recently and for a space of upwards of 50 years it has not been worked, Messrs. Brown and Clayton being the last persons to work this mine. It had then been worked, to a greater or less extent for many miles along the level and to a distance of 1,000 feet below the downcast shaft and above the shaft to the outcrop. These old workings are now charged with water lying between the outcrop and the unworked coal. Since that time, and up to the present company commencing operations, the colliery has successively been worked by Messrs. Bradbury and the Hyde and Haughton Colliery Company, who confined their attention to the peacock and two-feet mines, the latter company also working a small area of the third mine.

The unworked area of black mine had previously been overlooked or thought to be so deep as not to be within workable reach. At all events it has remained for the present owners, under the direction of Mr. John Higson, mining engineer, of Manchester, to drive the necessary tunnels from the two-feet mine to win the area of black mine remaining unwrought, after leaving barriers to keep the water lying in the old workings from finding its way into the newer workings. The mine dips at the rate of 1 in $2\frac{1}{2}$, and is 4 feet in thickness. The leaving of the barriers has caused practically the whole of the coal now being worked to lie in the deep of the main-level tunnel. To overcome, temporarily, this difficulty, a system of endless-rope haulage, worked by electricity, has been erected, and it is eventually intended to replace this system of hauling by means of gravitation. Neither the two-feet nor the peacock mines are being worked at present.

The black mine is worked on the longwall method, and the coal is brought to the main engine-brow by the endless-rope haulage before

mentioned. It is then hauled up this engine-brow to the shaft-bottom. The engine-brow consists of a dip-tunnel, driven from the shaft-bottom to the two-foot mine, 690 feet in length, and a brow driven in the two-foot mine to the point, at which the black mine is at present delivered, known as the No. 3 hooking-place, for a length of 1,050 feet. Just below the No. 3 hooking-place, a dip-tunnel dipping 1 in 6 and 600 feet in length, has been driven to the black mine, and the brow is being continued in the black mine in order to open a fresh "rank" of coal below that now being worked. The total length of the engine-brow is 2,910 feet, and the system of haulage is direct, there being two roads on which the tubs are run in gangs of 18. The hauling-engine is placed on the surface.

The two-foot mine, which at the outcrop consists of coal, becomes on the deep one-half cannel, and the change may be observed in the engine-brow, which is driven in the solid coal. This seam is the well-known cannel seam of the Dukinfield collieries. In order to deal with the water which has found its way down-brow in the peacock and two-foot mines, and to prevent it from entering into the newly-opened area of black mine, a force-pump has been placed at the No. 2 level in the two foot mine. This pump can deal with 10,000 gallons of water per hour if necessary, and pumps the water up a brow dipping at the rate of 1 in $2\frac{1}{2}$ and 1,200 feet in length to the shaft-bottom.

Steam is supplied by means of 5 Lancashire boilers, 2 being worked at a pressure of 75 lbs. per square inch, and 3 at 45 lbs. The feed-water is heated to 260 degs. Fahr., by means of a set of Green economizers.

The colliery was at one time ventilated by means of a furnace, but this has now been replaced by a Schiele fan 7 feet in diameter, producing 47,000 cubic feet of air per minute, the water-gauge being 2 inches. The fan-engine is worked by steam at a pressure of 45 lbs. per square inch at the boilers. The cylinder is 18 inches in diameter by $2\frac{1}{2}$ feet stroke. The engine runs at 56 revolutions per minute, and the fan is driven by a strap, from the fly-wheel of the engine, at about 300 revolutions per minute.

The Stanley and Davies excelsior dynamo or generator is capable of giving an output of 250 volts and 200 ampères at its normal speed of 500 revolutions per minute. The dynamo is driven by an horizontal engine, having 2 cylinders, each $14\frac{1}{4}$ inches in diameter by 2 feet stroke, running at 96 revolutions per minute. The connexion between the fly-wheel of the engine and the driving-pulley of the generator is made

direct by a link-leather belt 12 inches wide. The pressure of steam supplying these engines is 45 lbs. per square inch at the boilers. From the generator to the pump-motor, which is fixed down the pit 2,100 feet distant, the current is conveyed through a specially insulated stranded copper cable having a carrying capacity of twice the load. This cable is carried on porcelain insulators. Electric bells and a telephone connect the pump and hauling-engine houses in the mine with the surface electric engine-house.

The winding-engine has two horizontal cylinders, each 2 feet 6 inches in diameter, with a stroke of $4\frac{1}{2}$ feet. The diameter of the drums is 15 feet. The winding-engine lifts 4 tubs, placed on two decks, containing 32 cwts. of coals, at each winding, and is supplied with steam at a pressure of 45 pounds per square inch at the boilers.

The hauling-engine has 2 horizontal cylinders, each 16 inches in diameter, and $8\frac{1}{2}$ feet stroke, running at a speed of 160 strokes per minute, and hauls up the main engine-brow by means of best plough-steel wire ropes, 1 inch in diameter, which are conveyed down the downcast shaft. By means of a pinion placed on an intermediate shaft, and of a spur-wheel placed on the drum-shaft, the engine is geared to the load in the ratio of 4 to 1. The drums are 8 feet in diameter, and are both placed on the same shaft as the spur-wheel, and are worked by means of clutch gearing. Electric bells connect the engine-house with the underground workings. The engine is supplied with steam at a pressure of 75 pounds per square inch at the boilers.

The direct-acting pump is placed on the western side of the pit. The vertical steam cylinder slightly overhangs the pit, and is 60 inches in diameter, the length of stroke of the engine is 8 feet, and the length of stroke of the pump is 10 feet. There are two ram-pumps, the bottom one being 12 inches in diameter, and the top one 15 inches in diameter. The engine runs at the rate of 8 strokes per minute, and the quantity of water lifted is 220 gallons per minute. The cylinder is supplied with steam at a pressure of 75 pounds per square inch at the boilers.

An electrically-driven underground pump is placed in an engine-house off the No. 2 road in the two feet mine. The engine-house, 50 feet long, 15 feet wide, and 10 feet high, is lighted by electricity. The motor is of the same type as the generator at the surface, and will yield 40 horse-power when running at 700 revolutions per minute. This machine drives direct on to the pulley or pump-shaft by a link-leather belt 10 inches wide, driving the rams through one pair of spur-wheels; the pumps making 40 strokes per minute. The horizontal pump,

having 4 single-acting rams 8 inches in diameter by 8 inches stroke, is capable of lifting 10,000 gallons of water per hour.

The motor of the electric haulage-engine is connected to the generator at the surface by means of cables brought from those in the pumping engine-house, and runs at 800 revolutions per minute. The motor is placed at the end of the main level-tunnel from the two feet mine, in the black mine, and is connected by means of cotton ropes from the driving-wheel on the motor-shaft 18 inches in diameter with another wheel 5 feet in diameter. On the same shaft as the 5 feet wheel is placed a fast-and-loose pulley, 3 feet in diameter; this is connected by means of a leather belt with another wheel $5\frac{1}{2}$ feet in diameter, and on the same shaft is a pinion-wheel 10 inches in diameter, which drives a spur-wheel 18 inches in diameter. The same shaft carrying the spur-wheel also carries a bevel-wheel 18 inches in diameter, which drives an horizontal wheel 8 feet in diameter, which in turn drives the vertical shaft. On the vertical shaft are placed three pulleys which drive four roads, one being a brow 1,080 feet in length, and dipping at an angle of 1 in $3\frac{1}{2}$.

MANCHESTER CORPORATION'S HYDRAULIC-POWER STATION, GLOUCESTER STREET.

The Gloucester Street hydraulic-power station contains six overhead direct-acting triple-expansion engines, the cylinders of each engine being 15 inches, 22 inches, and 36 inches in diameter respectively, and all of 24 inches stroke. The engines are coupled direct to three single-acting ram-pumps $4\frac{1}{2}$ inches in diameter. The cranks are set at 120 degrees. Each engine and pump delivers 230 gallons of water per minute against a pressure of 1,120 lbs. per square inch, at a piston speed of about 240 feet per minute.

Each engine has surface-condensers, fitted with tubes to give a cooling surface of about 530 square feet, and each tube is fitted with a screwed gland packed with cotton. The condensers are arranged so that the water can circulate twice through the tubes. The air-pump is 15 inches in diameter by 16 inches stroke, and single-acting; it is made of cast-iron, lined with gun-metal, and fitted with rubber valves. The circulating-pump is 8 inches in diameter and 16 inches stroke, double-acting, and delivers 310 gallons per minute when the piston speed is 240 feet per minute.

The engines are arranged so that high-pressure steam can be admitted to the intermediate cylinder. The two accumulators are each 18 inches in diameter, and have a vertical stroke of 23 feet. The dead-weight is carried in a circular cistern, about $11\frac{1}{4}$ feet in diameter, filled with iron-slag.

The engines are coupled to four main delivery-pipes 6 inches in diameter. Air-vessels are fitted on the suction-pipes, one large one on the main, and two smaller ones close to the pumps. Air is pumped into these occasionally by a small portable force-pump.

In the streets, there are 71,280 feet or $13\frac{1}{4}$ miles of piping, including pipes of 3, 4, 5, and 6 inches in diameter. The flanges are oval, the joint being a bevelled he-and-she joint, securing a gutta-percha ring ($\frac{3}{8}$ inch) by two bolts. The pipes are laid in sections, tested to 2,000 lbs. per square inch, and are so divided by stop-valves that in the event of a breakage or bad joint, no greater length than 600 feet need be added by other routes to supply the surrounding mains.

In laying the pipes, the flanged joints were placed horizontally, and as in every case the workmen scooped a hollow for the reception of the flanges to get readily to the bolts—the joint is the weakest part of the pipe. Had the flanges been placed vertically, the pipe-joints would have been less likely to break, but the bottom bolts would have been more difficult to tighten.

Stop-valves and momentum-valves are placed on the main junctions of the supply-pipes. As the large valves under the pressure of 1,000 lbs. would be difficult to move, these are balanced by means of a small internal valve controlled by the main valve-spindle. Small momentum-valves are also placed on each side of the stop-valves. These valves are simply small rams $1\frac{1}{2}$ inches in diameter, spring-weighted, and in the event of any sudden shock in the flowing water, they act as displacement or relief rams.

There are five boilers, each $7\frac{1}{2}$ feet in diameter, 30 feet long, fitted with two flues, each 3 feet in diameter, and five Galloway tubes in each flue. The working pressure is 120 lbs. per square inch. Coal is delivered to the Vicar mechanical-stokers by spiral conveyors from the coal-hopper, and the ashes are removed by similar mechanical arrangements; the whole of the gearing being driven by a three-cylindere hydraulic engine.

**SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE
INSTITUTE OF MINING ENGINEERS.**

**GENERAL MEETING,
HELD IN THE MASON COLLEGE, BIRMINGHAM, APRIL 1ST, 1897.**

MR. R. S. WILLIAMSON, PRESIDENT, IN THE CHAIR.

The minutes of the last General and Council Meetings were read and confirmed.

The following gentlemen were elected:—

MEMBERS—

**Mr. ROBERT PEELE, Adjunct Professor of Mining, Columbia University,
New York.**

Mr. RICHARD S. McCaffery, Mining Engineer, Lima, Peru.

Mr. ERNEST J. BAILEY read the following paper on “Saving Life in Colliery Explosions” :—

SAVING LIFE IN COLLIERY EXPLOSIONS.

By ERNEST J. BAILEY.

Having read with great interest Dr. Haldane's paper, "The Causes of Death in Colliery Explosions,"* and the discussions that have taken place thereon, the writer has been very much struck with the utmost importance which attached to several facts elucidated by Dr. Haldane, especially with regard to the large percentage of lives lost in colliery explosions from the effects of after-damp only. The composition of after-damp and the peculiar nature of its effects are both now clearly understood, and in the main agreed upon by medical men, but the potent fact clearly stood out that about 70 per cent. of the lives lost in explosions might be saved—but for the after-damp—and that the proportion of lives lost from actual violence, burns, or other injuries was very considerably the smaller one.

It is therefore incumbent upon mining engineers to consider these facts and turn their attention not only to the prevention of colliery explosions, but also in the event of one taking place to the provision of some life-saving appliance if any can be found. Dr. Haldane wrote :—

Considering the risks of an explosion in any fairly dry pit, however free from fire-damp, arrangements should be made beforehand for minimizing, as far as possible, the loss of life should an explosion occur. In the first place, he feels certain that means might be devised for shortening the time which usually elapses before fresh air is again circulating through, at least, the main roads after an explosion.†

Dr. Haldane also drew attention to the always fatal delay in restoring ventilation, owing to damage to ventilating-fan, air-crossings, doors, stoppings, etc. The truth of these facts cannot be doubted, and must come home very forcibly to those engineers who, like the writer, have had the unhappy experience of dealing with an explosion.

As before stated—in most cases of a serious explosion—injury to the ventilating-fan, the fan-drift, or the covering of the upcast shaft, causes an almost total stoppage of the ventilation in the workings ; or injury to

* *Trans. Fed. Inst.*, vol. xi., page 502. † *Ibid.*, vol. xi., page 511.

the doors, air-crossings, stoppings, etc., causes a short circuit of the air-current, whereby the working-faces are left totally without fresh air. The men in these places knowing this, and that there is no chance of any fresh air being conveyed to them when the ordinary means of ventilation are stopped, or disorganized, naturally make for the shaft by the nearest way at any risk with the terrible consequences so often recorded, and those who do remain behind as a rule suffer sooner or later, the same dreadful fate.

Mr. Bailes, in discussing Dr. Haldane's paper pointedly remarked that "Unless persons were certain that the air would remain pure at the working-faces, they would not stop at the in-bye end."*

Mr. Simon Tate in a paper read before The North of England Institute of Mining and Mechanical Engineers in 1894† suggested an ingenious plan of so arranging the workings of a mine that one portion affected by an explosion could be shut off from the other portions by means of doors fixed in suitable positions, and in this way the unaffected air enclosed would keep alive the men imprisoned for a considerable time and free from after-damp. The discussion which followed the reading of the paper brought forward arguments for and against this idea; one of Mr. Tate's remarks however again sets forth the point at issue, viz. :—

If the workmen left alive and uninjured by the force of an explosion could be rescued, colliery explosions would be deprived of some of their most terrible consequences and the number of lives lost would be considerably diminished.‡

The writer's object in bringing this matter again before the Institute is for the purpose of placing before the members an idea that he had conceived of carrying out means to meet life-saving requirements from after-damp after explosions, which he believed would prove effectual in many cases. It appeared to him that the object to be aimed at is twofold :—

(1.) To supply fresh air at the earliest possible moment after an explosion to the men in the workings, who may be imprisoned by falls or otherwise.

(2.) To afford a continual supply of fresh air to those workmen in a temporary place of safety and protect them from the effects of after-damp until the roads between them and the shaft are explored by rescuers and made safe.

* *Trans. Fed. Inst.*, vol. xi., page 561.

† *Ibid.*, vol. viii., page 189.

‡ *Ibid.*, page 189.

To provide this fresh air immediately after an explosion, and also to continue a supply as long as may be necessary, the writer suggests :— That in all fiery and dusty mines, compressed air should be laid on to certain approved stations in the workings by means of pipes connected with an air-compressor on the surface. It is within the means of almost all collieries to provide a suitable plant of sufficient power for this purpose, and the writer thinks that he would be within the mark in asserting that nine out of ten large collieries already possess compressed-air machinery of some kind which could supply the required air in case of need.

Fig. 1 (Plate IV.) is a section which will explain the writer's ideas :— in which *SS* is the downcast shaft, and *P* is the compressed-air plant at the surface.

By carrying a main line of pipes *P* (Fig. 2, Plate IV.) to the stations marked *A, B, C, D*, near to the working-faces, a supply of fresh air could be delivered there at a few minutes' notice. These stations should be very clearly marked in the mine, and made known to all workmen. The pipes should always be kept connected to the air-compressor by suitable connecting-pipes, and frequently tested by filling them with air, so that leaky joints could be detected and at once made perfect. At the stations taps, and, if necessary, keys to them, could be provided, only to be used in case of need, or for testing their efficiency and working order. The pipes, *P*, should be laid a little underneath the floor of the roads, almost up to the stations, so that they would escape injury by falls of stone, etc., or the violence of an explosion.

The air-compressor on the surface should be placed in such a position as to be uninjured by an explosion, and the pipes in the shaft should be well protected. It is noticeable that in recent explosions pipes and fittings in shafts have escaped injury. A colliery being thus provided, after an explosion had occurred attention would immediately be given to the air-compressor and pipes, to see that there was no defect in them as far in-by as it was possible to go. In the workings the men, being aware of the pipe-stations and their use, would make their way to these points, turn on the air, and make themselves temporarily safe, by bratticing, from after-damp. A plentiful supply of brattice cloth should be always kept at the stations. The number of the stations and their positions would be determined according to the various requirements of the working and ventilating districts of the mine.

It would be a matter of considerable relief to workmen suddenly imprisoned by an explosion to know that there was some direct communica-

tion between them and the surface, and give them confidence to remain safely at the stations and calmly await help.

From practical experience, the writer knows what a very small quantity of compressed air will ventilate a gaseous heading, where pumps or coal heading-machines are in use worked by compressed air.

It had been mentioned that a dangerous result follows forcing fresh air into mines after an explosion, owing to its effect upon fires of burning timber, or smouldering dust which may have arisen in consequence. The compressed air from the writer's suggested pipes, although sufficient to keep a number of men alive, would be confined to small areas, and the men could easily arrest small fires at their outset before they assumed serious proportions. The notifications of fires after an explosion have been comparatively few.

The cost of applying the scheme to a colliery whose workings are shown on the accompanying plan (Fig. 2, Plate IV.), given at the end of the paper in detail, works out as follows :—

- (1.) For a colliery where air-compressor, engine, and pipes have to be purchased and laid down, about £1,000.
- (2.) Where air-compressor and pipes would be required, about £750.
- (3.) Where pipes only are required, about £450.

The cost of pipes would, of course, vary according to the distance of the working-faces from the shaft. The cost of maintenance would be chiefly incurred in keeping the pipes intact—owing to the heaving or lifting of the floor of the roads injuring, or perhaps breaking, the joints. In very many mines where the floor is not subject to lifting, the cost of repairs to pipes would be very slight indeed. The cost of lengthening the pipes, so as to keep the stations well within reach of the working-faces, would be a nominal one in an ordinary colliery.

With regard to the question of cost, it might be mentioned that in some collieries duplicate ventilating-fans are erected so as to provide against any lengthy stoppage of ventilation in case of an explosion, and this plant must far exceed the cost of compressed-air plant and pipes in ordinary collieries. When we consider that an explosion destroys the guiding courses of the ventilation, in 9 cases out of 10 a duplicate ventilating-fan would really be of little or no use in supplying air to the in-by workings.

Trouble and expense must necessarily accompany any life-saving appliances in mines, and no appliance could be devised of this kind to have due effect under some conditions. The writer firmly believes, how-

ever, after considering the effects of some of the more recent explosions that his idea, if carried out, would have been effective to some extent in most of these cases.

The writer has prepared Figs. 3 and 4 (Plate IV.) from the plans accompanying the reports to H.M. Secretary of State for the Home Department on the Albion and Micklefield Colliery Explosions. It will be seen on looking at the plan (Fig. 3) of the Albion colliery that most of the bodies were found near to the working-faces, and the cause of death in all these cases was after-damp. Had compressed-air stations been available, say, at the points *A, B, C, D, E, F,* and *G*, the men around would at least have had a chance of breathing pure air until the rescuers reached them. The bodies found on the shaft side of the suggested air-stations were those mutilated by the force of the explosion. The same remarks apply, though in a smaller degree, to the Micklefield plan (Fig. 4) where air-stations at *A, B, C, D, E, F,* and *G* would no doubt have saved the lives of the workmen whose bodies lie around those points.

Dr. Haldane in his report referring to the Albion explosion said that all men in the Pantddu district might have been saved had they waited till the after-damp in the roads had dispersed. This statement shows how useful it would be to have marked safety-stations in the workings, and an immense deal would be gained if the men could only be got to gather together near the face instead of rushing into the after-damp in the usual way.

With regard to the quantity of air required for the purposes of rescue, Dr. Haldane estimated that 100 cubic feet of air would suffice to keep a man alive for 10 hours, so that the air from, say, an air-compressor, with a cylinder 20 inches in diameter and 4 feet stroke, would give sufficient air to keep a very large number of men alive if judiciously distributed.

With regard to the rescuers in explosions, Dr. Haldane in his report frequently referred to their anxiety in pushing forward to the men imprisoned without having properly restored ventilation as they go, thus, incurring great risks themselves. The provision of the air-stations would give rescuers more time for the restoration of the permanent ventilation and enable them to do their work at less risk to themselves.

Laying water pipes for watering dust in main roads underground is now general in dry collieries, and though the writer would hesitate in putting any additional burden on the already heavily taxed colliery proprietor, he thinks that no matter how remote the possibility of an

explosion may be, it would be well to consider the question of laying down air-pipes also, especially in gaseous and dusty mines.

No colliery manager thinks it, as a rule, probable that an explosion may occur at the particular colliery under his charge, and it had been suggested that to provide for one was like a man ordering a coffin before his death. It could not be denied, however, that calamities often happened where least expected, and if anything could be done to save life after an explosion and lessen its terrible effects, it surely ought to be done.

To attempt to deal with this subject in a single paper would be sure evidence of never having studied it. The writer, therefore, leaves it thus incomplete, trusting that the idea may in the course of discussion be turned to some account, or at any rate lead to useful suggestions for the furtherance of the important object so often before mining engineers.

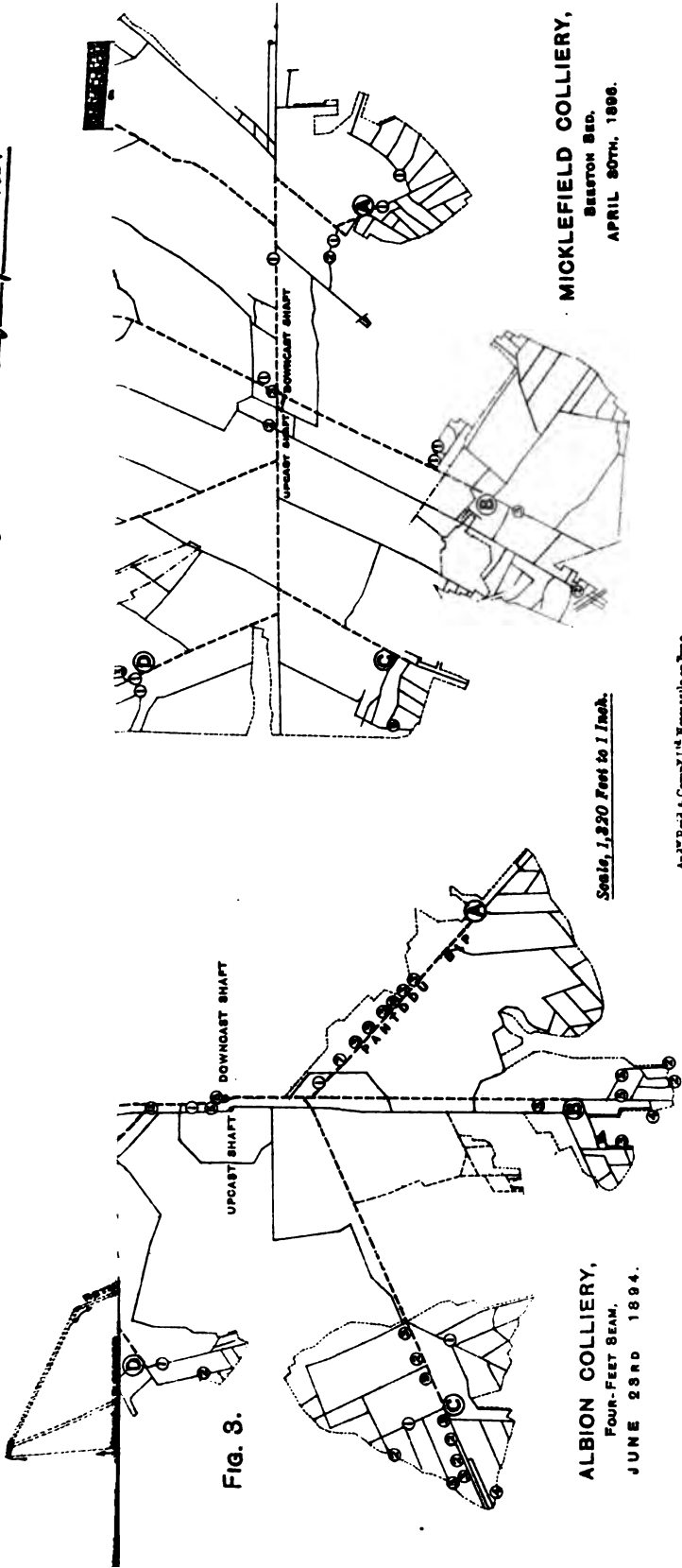
APPENDIX.

APPROXIMATE COST OF AN AIR-COMPRESSING LIFE-SAVING APPARATUS.

Air-compressor, cylinder 20 inches in diameter and 48 inches stroke	...	...	...	...	...	£	s.	d.
Fixing, etc.	...	...	...	...	...	250	0	0
Steam-engine to drive air-compressor, cylinder 16 inches in diameter and 48 inches stroke	...	...	...	...	...	200	0	0
Fixing, etc.	...	...	...	...	...	50	0	0
Pipes, 2,500 feet of wrought-iron pipes 3 inches in diameter, including fixing, at 1s. 9d. per foot	...	...	...	...	...	218	10	0
Pipes, 3,500 feet of wrought-iron pipes 2 inches in diameter, including fixing, at 1s. 2d. per foot	...	...	...	...	...	204	0	0
Connexions, bends, cocks, keys, and sundries	...	...	...	...	...	28	10	0
						£1,000	0	0

Dr. JOHN S. HALDANE (Oxford) remarked that it was only engineers of practical experience who could give very definite opinions upon the suggestions made in Mr. Bailey's interesting paper; but that, so far as he understood the practical bearings of the paper, they seemed to him of great value. He saw no reason why, if the system which Mr. Bailey suggested was adopted, a very large number of men should not escape with their lives after an explosion. At the Albion colliery explosion, it was found in

To illustrate Mr. Ernest J. Bailey's Paper on "Saving Life in Colliery Explosions."



one district that horses survived, while in the others there was not sufficient air to support life. It seemed that the men left the face of the workings, where the air was fresh enough to support a horse, and ran towards the main roads, where they succumbed. If there had been compressed-air stations in another district where 37 poor fellows were found, he thought that all of them would have escaped.

He was quite of opinion, too, that at the Micklefield colliery explosion, the men would have easily escaped if there had been air-stations. Only a small percentage of the men killed were burnt or touched by the explosion, and all the bodies were found in the roads leading towards the shaft. The air close to the face was fresh, but the men ran from it into the roads. There could be no doubt whatever that Mr. Bailey's plan would be of considerable importance in the case of underground fires, and if the men knew where they could find compressed-air stations they would escape many dangers. It appeared to him that in all cases the system would be a great means of saving life if a sufficient quantity of air could be pumped in, and the falls, which were very large in explosions, did not damage the pipes. He would, however, suggest that the stations should be placed in accessible positions and clear of haulage-roads.

The discussion was adjourned.

DISCUSSION ON MR. NICHOLAS TRESTRAIL'S PAPER ON "THE DUTY OF CORNISH PUMPING-ENGINES."*

Mr. CHAS. H. TREGLOWN said that very high records of duty were given, but in some instances for various reasons Mr. Trestrail did not apparently attach perfect reliability to the records. The statement in the test, made at the Rio Tinto mines, that the consumption of about 17 lbs. of steam per indicated horse-power, with a single cylinder, seemed open to further explanation; and at Carn Brea mine, with a crooked shaft and more than 2,200 feet of pitwork, cutting off earlier than one quarter with a stroke of 10 feet, it would be interesting to see the indicator diagrams.

The author said that one of the objects of his paper was to invite engine-owners to adopt some standard system of independent reporting. He had no purpose in questioning the correctness of the issued reports of the "Cornish pumping-engine trials," but he had long considered them incomplete and unsatisfactory to all concerned.

* *Trans. Fed. Inst.*, vol. xii., page 548.

He did not think that any suggestion had been made as to the use of the indicator, but the indicated duty gave the actual total load, which in all fairness to the engine should be known. It embraced the effective or useful work done and the power required for dealing with non-useful work, giving the opportunity of judging whether savings could be made in the coal charges. The quality of coal and efficient stoking were undoubtedly important factors in the degree of duty of any engine ; but with prices, rates of consumption, and occasional evaporative tests, comparisons could be made which unquestionably would help to determine how the interests of the owners could be generally well served.

Owing to the depressed state of the Cornish mining industry, he thought that the most important question was : could pumping machinery be improved, and the heavy pumping charge reduced ? He had observed no suggestions from Mr. Trestrail in this direction, but if his paper should lead to increased efficiency and greater economy he was sure that Mr. Trestrail would never regret the time and labour which he had spent in preparing it.

Mr. THOMAS PASFIELD thought that the fallen duty of the Cornish pumping-engine was due to a great extent to the inferior coal used, which was of a much less calorific value than the best Welsh coal. An inferior coal at 10s. 6d. per ton, and a duty of 60,000,000 foot-pounds were more economical by 27 per cent. than best coal at 25s. per ton and a duty of 105,000,000 foot-pounds.

The PRESIDENT expressed concurrence with some of Mr. Treglown's opinions, and observed that in the South Staffordshire district, where they were subject to a mines drainage-rate of 9d. per ton, they would gladly welcome anything which could be brought forward to reduce it.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND
MECHANICAL ENGINEERS.

STUDENTS' MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
JANUARY 30TH, 1897.

MR. G. P. CHAPLIN IN THE CHAIR.

The following "Notes on Coal-mining," by Messrs. Algernon Noble and N. Nisbet, were read :—

NOTES ON COAL-MINING.

BY ALGERNON NOBLE AND NORMAN NISBET.

Methods of Working Coal.—Under this heading will briefly be noticed methods of working the coal in mass and the operations necessary at the face.

It is desirable that the mineral should be extracted :—(1) With the least danger to life; (2) with the least possible expenditure; (3) with the least loss of coal in extraction; and (4) in as good a marketable condition as possible.

The two great methods, namely, that of taking the coal out in one operation, and that in which the coal is taken out in two or more operations, with their infinite capacity for modification, practically meet all the requirements which they are called upon to perform. There are, however, certain points that must always be considered in settling upon a method of working. They may be briefly summarized as follows :—Depth of seam from the surface, thickness, dip, and nature of seam, and nature of the adjacent strata. There are, however, other innumerable smaller circumstances peculiar to each individual case, and these must modify to a greater or less extent the method pointed out by principles deduced from the above-mentioned facts.

To the practical experience gained in actual working must be added a knowledge of the experiences of others, and although it may be said to be impossible to get the same circumstances together in any two cases, yet they may generally coincide and form a basis for future working.

The writers will describe one example of longwall and bord-and-pillar working, of which they have had practical experience, in hard steam coal and soft gas coal respectively.

(A) In the longwall workings at Broomhill colliery, all the coal is taken out and roads kept in the goaf as the face advances. The coal-seam is worked on end and is a hard steam coal. The seam lies at a depth of about 162 feet below the surface, and has the following section :—

Not worked—				Ft.	Inch.	Ft.	Inch.
Top coal	...	...	...	1	1		
Stone	...	...	...	0	5		
Coal	...	...	...	1	1		
Stone	...	...	...	0	5		
				—		3	0
Worked—				Ft.	Inch.	Ft.	Inch.
Coal	...	...	...	2	11		
Clay	...	...	...	1	9		
				—		4	8
Not worked—				Ft.	Inch.	Ft.	Inch.
Bottom coal	...	...	...	1	0		
				—		1	0

This seam was first worked on the bord-and-pillar system, but owing to the surface-damage which this method caused, longwall was tried and proved entirely satisfactory. The only indication of the workings on the surface is a hardly perceptible fall along the line of face. The method of working is shown in Fig. 1 (Plate V.). The upper coals and stone (3 feet) are taken down in the gateways for height. The lower coal is left unwrought.

The underclay is shot out, leaving the coal intact, to a depth of 5 or 6 feet. There are two workmen in each gateway, and they usually work about 33 feet on each side. While one man is blasting out the underclay and packing it in the goaf on one side of the gateway, his fellow workman is filling coals on the other side. Chocks are built about 3 feet apart at each side of the gateways as the face advances. Chocks are built in the goaf, between the gateways, where the roof is exceptionally bad. Cross-gateways are turned away at an angle of about 70 degrees, at intervals of 150 feet. After the last working-place is cut by a new cross-gateway the old gateway is abandoned, and either stowed or allowed to close itself. This method works admirably, and the maximum amount of round coal is obtained from the seam.

(B) The following instance of working a seam 10 to 12 feet by the bord-and-pillar method is in vogue at Tanfield Lea colliery.

The hutton coal-seam, lying at a depth of about 400 feet, has the following section :—

Roof.					Ft.	Ins.	Ft.	Ins.
Top section—								
Coal	...	...	...	...	3	0		
Parting	...	...	...	...	—			
Coal	...	...	...	...	2	4		
Parting	...	...	...	...	—			
							5	4
Bottom section *—								
Coal	...	...	...	...	1	11		
Band	...	...	...	...	0	2		
Coal	...	...	...	...	3	0		
							5	1
Fire-clay.								

* Worked in whole or first working.

It will be seen that there are two partings, one at 5 and the other at $7\frac{1}{2}$ feet from the floor. All the whole working is carried out in the bottom section of the seam up to the lower parting. Pillars are made 66 feet square from centre to centre of the working-places. The headways are driven 6 feet and the bords 12 feet wide. Coal is taken down to the upper parting on the rolleyways. The seam has a slight dip of about $\frac{1}{4}$ inch per yard. In working the broken, each pillar is divided into three equal parts by two fast siding-overs *A*, each 6 feet wide, up to the lower parting, and holed into the goaf (Fig. 2, Plate V.). The top coal in the inbye siding-over is shot down a distance of 12 or 15 feet back from the goaf-edge, and a lift *B* is turned away the full height of the seam. It will be seen from the plan that the lifts are about 15 feet long. The tramway is laid down next the fast side of each lift. The timbering in the lifts consists of pairs of props 10 feet long, placed on either side of the way, capped by crown-trees and supplemented by wooden chocks built of pieces 2 feet long and 6 inches by 4 inches, where necessary. Three lifts about 15 feet wide are driven out of each siding-over ; and the remaining lift or stook, loose on both sides, and the top coal in the bord is cut up in line with the siding-over and worked simultaneously with the last lift.

Coal-getting at the Working-face.—The advantages claimed for the substitution of mechanical for manual labour at the coal-face are : reduced cost, a larger proportion of round coal, a reduction in the number of workmen employed and a consequent reduction of the possibilities

of accident, and greater concentration of work, so that less capital expenditure is necessary for the maintenance of haulage-roads and necessary plant. On the other hand, there are many disadvantages. Faulted ground is difficult to work with mechanical coal-cutters; the conditions of floor and roof must be favourable; the use of coal-cutters is undesirable in a seam of variable dip; the machine is difficult to manage in the confined spaces that obtain in a coal-mine; there are obvious objections to the use of electrical coal-cutters in fiery mines; wet or damp mines are unfavourable to the use of electricity; and when compressed air is the motive power the efficiency is low.

The majority of coal-cutters which have been invented up to the present time are more adapted to the longwall than to the bord-and-pillar method of working; in fact, the system of working which is best adapted for coal-cutting is undoubtedly longwall. In the event of a coal-cutter breaking down, the loss entailed would be equal to that caused by the absence of a considerable number of hewers.

In most of the instances in which mechanical coal-cutting has been tried, one of the chief difficulties has been the inability to remove the undercut coal in time to allow of the machine retracing its path. This, however, is only one of those difficulties which, in a seam being laid out specially for mechanical coal-cutting, would be specially provided for. The most successful applications of the mechanical coal-cutter appear to have been in thin and hard seams. Whether the adoption of coal-cutting machinery will become general or not it remains for the future to solve.

Transit or Haulage.—The haulage of mineral from the working-faces to the shaft or other outlet is accomplished by a variety of methods, the power being applied—(a) by manual labour, as in hand-putting; (b) by horses and ponies; or (c) by mechanical appliances. As a rule, the coal in its transit from the working-faces to the shaft is conveyed by nearly all three methods. At the outset, it may be advisable to give the comparative costs of the above-mentioned methods of haulage :—

			s.	d.
Hand-putting, per ton per mile	...	...	3	2
Pony-putting " "	...	...	2	6
Horse-haulage " " "	...	...	0	7
Rope or chain-haulage	...	...	0	2

The above costs include maintenance, depreciation, etc., but are exclusive of interest on capital expenditure. Hand-putting is only used where pony-putting is difficult, on account of limited height. The excessive cost of pony-putting and hand-putting renders their curtailment desir-

able. Horse-haulage shows a considerable decrease in cost as compared with hand and pony-putting, and is employed to lead coal from the stations (where it is brought by hand or pony-putters) to the engine-planes.

The low cost of mechanical methods of haulage as compared with those above mentioned renders the introduction of mechanical appliances desirable wherever possible. Since mechanical haulage replaced the older methods of horse-haulage, the tendency has been to apply the power by means of ropes from a fixed engine, and locomotives have only been used in special cases. The objections to the use of steam locomotives in coal-mines are numerous, and in the majority of cases absolutely prohibitive. Locomotives driven by compressed air, and also by electricity, have been tried, but without economical results.

Admitting that it is an essential to the cheapening of the cost of haulage to use mechanical means wherever possible—the question arises, what form of mechanical haulage is best adapted for this purpose? Here, again, come into play the uncertain and variable conditions of mining. In some mines it would be impossible to maintain a sufficient width of road to introduce an endless-rope method of haulage. In other mines, steep and variable gradients may be just as prohibitive to the adoption of the main-and-tail-rope method.

Both endless-rope and main-and-tail-rope have done very economical work, but apart from this point, the question still remains to be answered—which of these systems of haulage, or what new system can be devised to do away with the expensive method of using animal power? In the main-and-tail-rope method of haulage, it is obvious that a large engine will be unable to cope economically with small trains on horse-roads. It is sometimes possible to continue endless-rope haulage along horse-roads, but only by a large capital expenditure and the amount of coal to be wrought by the horse-road may not be very large.

Is it more economical, then, to extend the primary system of haulage to the horse-roads or to confine it to the main ways and institute secondary systems of rope-haulage for the different districts worked by auxiliary hauling-engines?

The condition upon which this method of using auxiliary engines for haulage is chiefly dependent for its successful application is that of the transmission of power to the auxiliary engines. This transmission has been effected in some cases by means of compressed air, and as many as fifteen small hauling-engines have been so operated at one colliery. The writers think, however, that this is a case of transmission of power to which electricity is peculiarly applicable. The electric energy should be con-

ducted by means of high-pressure leads to judiciously placed power-stations, where by means of transformers, the high-pressure current would be reduced to a safe working-pressure of about 300 volts. From these stations, electric power could be distributed to motors at hauling-engines, etc.

At present, the great disadvantage of this method is the unsafe nature of electricity in fiery mines, and if this risk could be removed the introduction of small auxiliary engines actuated by electricity distributed from central power-stations would, no doubt, reduce the cost of haulage to a considerable extent.

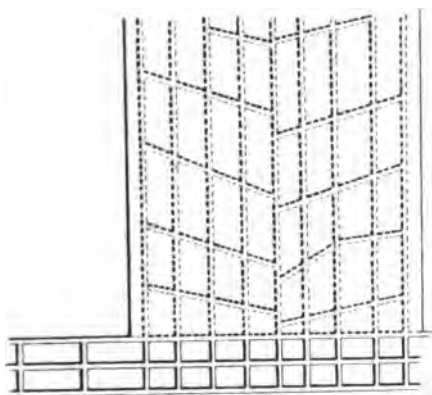
There are seven self-acting inclines in use at Broomhill colliery, and two of the methods used are shown in Figs. 3 and 4 (Plate V.). In the system shown in Fig. 3, the empty sets always ascend by the middle way at the top of the bank. In Fig. 4, the movable rail *B* is moved after each run. *A* is a self-acting point, and the full tubs, in running down the incline, shift this point so that the empty tubs will ascend up the same side.

The CHAIRMAN moved a vote of thanks to the authors for their paper, which was agreed to.

Mr. JOHN BROWN read the following paper on an "Eccentric Haulage-Clip":—

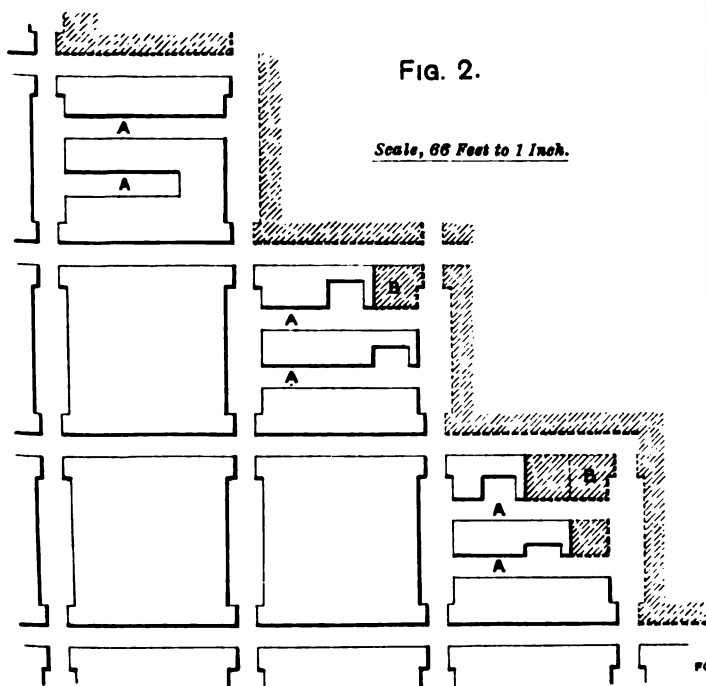
To illustrate Messrs A. Noble and N. Nisbet's "Notes on Coal-mining."

FIG. 1.



Scale, 400 Feet to 1 Inch.

FIG. 2.



Scale, 66 Feet to 1 Inch.

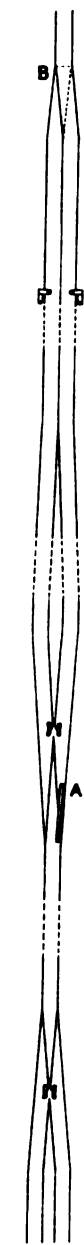
FIG. 3.

FIG. 4.

TOP OF INCLINE



TOP OF INCLINE



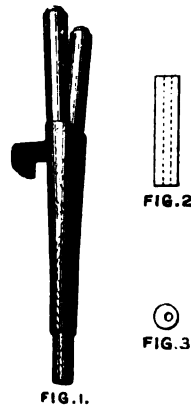
FOOT OF INCLINE FOOT OF INCLINE

Scale, 24 Feet to 1 Inch.

ECCENTRIC HAULAGE-CLIP.

By JOHN BROWN.

The writer proposes to describe a very useful clip that will give every satisfaction, no matter how the gradient of the seam changes, as long as the rope remains on the top of the tub. It will be seen by Fig. 1 that the clip does not hold the tub to the rope at one point. When the tub ascends a gradient of, say 1 in 7, and then descends a gradient of 1 in 7 the two points of the rope held by the clip will vary about 5 inches, and by this means the position of the clip on the rope is not constant at one place. Again, if the tub is to ascend a steep gradient for a certain length of road and the remainder of the road is level, the pressure on the rope is not the same throughout the whole distance, as the clip grips the rope, according to the gradient, just sufficient to overcome the friction and gravity of the load, and the wear and tear of the rope are thereby much reduced. When in use, this clip will require no attendant to hook it on or to loose it from the rope, and, consequently, the expense of endless-rope haulage will be reduced.



This clip, which is intended for use on systems of endless-rope haulage where the rope runs on the tub, is illustrated in Fig. 1. It consists of a yoke fitted to one end of the tub, with two vertical forks, each carrying a loose roller which acts as a cam, owing to the hole being placed eccentrically, as shown in Figs. 2 and 3. The rollers can turn freely on the forks, and the thick sides grip the rope at the speed at which it may be travelling. The forks are made of such a width apart, so that the thin side of the rollers will not allow the rope to run between them without turning round until the thick side grips the rope. For a rope $\frac{3}{4}$ inch in diameter, the space between the rollers should be $\frac{5}{8}$ inch at the bottom, at the thin sides, and 1 inch at the top.

A vote of thanks was accorded to Mr. Brown for his paper.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND
MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
FEBRUARY 13TH, 1897.

MR. GEORGE MAY, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on January 30th and that day.

PORTRAIT OF THE LATE MR. NICHOLAS WOOD.

The SECRETARY reported that Messrs. W. C. and G. R. Cockburn had presented an oil painting of the late Mr. Nicholas Wood, the first President of the Institute, and an unanimous vote of thanks was accorded to them.

The following gentlemen were elected, having been previously nominated :—

MEMBERS—

- Mr. CHARLES FITZ-HUGH ANDREWS, Mining Engineer, Isaac's Harbour, Guysborough Co., Nova Scotia.
- Mr. G. PERCY ASHMORE, General Manager to the Caylloma Silver Mining Co., Ltd., Caylloma, Peru, South America.
- Mr. SEPTIMUS J. BECHER, Temporary Government Inspector of Mines for the Northern Gold-fields, Western Australia, c/o Mr. H. Princep, Under Secretary for Mines, Perth, Western Australia.
- Mr. JOSEPH CAMPBELL, Consulting Geologist and Chemist and Principal of St. Nicolas College, Randwick, New South Wales.
- Mr. THEO. B. COMSTOCK, Mining Engineer and Metallurgist, Prescott, Arizona, United States of America.
- Mr. ARTHUR DE WINTÉ FOOTE, Engineer, P.O. Box 491, Grass Valley, California, United States of America.
- Mr. WILLIAM HEDLEY, Colliery Manager, Ouston House, Chester-le-Street.

- Mr. WILLIAM JAFFREY, Civil and Mining Engineer, 3, Victoria Street, London, S. W.
 Mr. JOSEF KLAUKE, Engineer, Esh Village, near Durham.
 Mr. CECIL E. NORTHCOTT, Mining Engineer, c/o Mr. G. Graves Gifford, Coolgardie, Western Australia.
 Mr. WILLIAM VAN SLOOTEN, Mining Engineer and Metallurgist, 52, Sidney Place, Brooklyn, New York, U.S.A.
 Mr. WILLIAM ALEXANDER YOUNG, Mining Engineer, 16, St. Helen's Place, London, E.C.

ASSOCIATE MEMBERS—

- Mr. J. B. ATKINSON, Lynwood, Egremont, *via* Carnforth.
 Mr. NOEL GRIFFIN, Havenhurst, Berkhamsted, Herts.
 Mr. ALBERT HODGSON, P.O. Box 212, Buluwayo, Rhodesia.
 Mr. WILLIAMSON HOLLAND, 65, William Street, Heywood, Lancashire.
 Mr. JOHN PRINGLE, Chinese Engineering and Mining Co., Tong Shan, Tientsin, North China.
 Mr. PERCY WEBSTER SMITH, Crichtons, Romford.
 Mr. BASIL WILLIAM TURNER, 40, Collins Street, Annandale, Sydney, New South Wales.
 Mr. FRED. C. WEHNER, c/o Senor Don Carlos Wagner, Arequipa, Peru, South America.

ASSOCIATES—

- Mr. JOHN CLOUGH, Surveyor, No. 1, Melton Terrace, Seaton Delaval Colliery, R.S.O.
 Mr. JOHN FEWSTER, Colliery Cashier, Coldwell House, Felling, R.S.O.
 Mr. A. HUNTER, Surveyor, Felling Colliery, near Newcastle-upon-Tyne.
 Mr. JOHN TOM MANDERSON, Assistant Surveyor, Seaton Delaval Colliery R.S.O.
 Mr. JAMES HEPPLE MARR, Assistant Colliery Manager, Birtley, Chester-le-Street.

STUDENTS—

- Mr. WILLIAM BELL, Mining Pupil, Elswick Collieries, Newcastle-upon-Tyne.
 Mr. ROBERT ROUTLEDGE, Mining Student, Murton Colliery, near Sunderland.
 Mr. WILLIAM RICHARD RUMBOLD, Student, Durham College of Science, Newcastle-upon-Tyne, and Mill House, Holmwood, Surrey.
 Mr. JOHN SMITH TWEDDELL, Mining Student, Seaton Delaval Colliery, Northumberland.

 REVISION OF BYE-LAWS.

The SECRETARY read the following proposed alterations of bye-laws 13 and 17, recommended for adoption by the Council :—

- 13.—The *Transactions* of the Institute shall not be forwarded to those whose subscriptions are in arrear on the first of November in each year.

17.—Any Member, Associate Member, Associate or Student may, at any time, compound for all future subscriptions by a payment in accordance with the following scale :—

Under 30 years of age, the sum of £31			
Over	30	„	27
„	40	„	24
„	50	„	21
„	60	„	17

or on such other conditions as the Council may, in writing, accept. Every person so compounding shall be a Member, Associate Member, Associate or Student for life, as the case may be. Any Associate Member, Associate or Student so compounding who may afterwards be qualified to become a Member, may do so, by election, in the manner described in Bye-law 8. All compositions shall be deemed capital money of the Institute.

DISCUSSION UPON THE “REPORT OF THE PROCEEDINGS OF THE EXPLOSIVES COMMITTEE.” *

The SECRETARY read the following letter from the Secretary of State for the Home Department, respecting the use of the plant erected at Hebburn for testing explosives to be used in mines :— †

WHITEHALL,

February 1st, 1897.

SIR,—With reference to your letter of the 10th October last, I am directed by the Secretary of State to acquaint you, for the information of the President and Council of The North of England Institute of Mining and Mechanical Engineers, that he has appointed a Departmental Committee to inquire into the question of testing explosives for the purpose of the Coal Mines Regulation Act, 1896 ; and that as at present advised he thinks that the plan to be followed will be the establishment of a new government testing-station near London. In these circumstances, although he appreciates the kind offers of the Institute conveyed in your letters of the 28th February, 1896, and the 10th October last, he does not think that he will be able to take advantage of them, nor can he hold out any hope that the suggestion that the plant established at Hebburn should be permanently retained and used as a testing-station under government patronage will prove feasible.

I am, Sir, your obedient Servant,

HENRY CUNYNGHAME.

M. Walton Brown, Esq.,
Secretary to the North of England
Institute of Mining and Mechanical Engineers,
Newcastle-upon-Tyne.

* *Trans. Fed. Inst.*, vol. viii., pages 227 and 593 ; vol. ix., pages 115, 206, and 274 ; vol. x., pages 38, 197, 492, and 503 ; vol. xi., pages 175, 218, and 551 ; and vol. xii., pages 51 and 179.

† *Ibid.*, vol. x., page 38 ; and vol. xii., page 179.

DISCUSSION ON THE REV. J. CAMPBELL'S PAPER ON
"THE GOLD-FIELDS OF THE HAURAKI PENINSULA,
NEW ZEALAND." *

The Rev. JOSEPH CAMPBELL wrote that he was glad to have had an opportunity of reading the criticisms upon his paper. With regard to Mr. Bewick's remarks as to the low value of the gold, it was well known that most of the gold from the Hauraki field contained a large percentage of silver, hence the comparatively low value.

The observations of Mr. S. H. Cox were very interesting, and deserving of careful attention. He (Mr. Campbell) could only reply that authorities differed; but if further examination proved that he was wrong in any of the particulars to which he (Mr. Cox) referred, he (Mr. Campbell) should readily admit his error. He thought, however, that it would be found that in the main his statements were in accord with those of Prof. Hutton.

In reference to Mr. Cadell's remarks, he would like to mention that when he began to write his paper on shipboard he intended entering very fully into the characteristics of the whole field, but on his arrival in London he was unwillingly compelled to cut it very short and leave out many matters of importance. What appeared at first sight as extraneous matter was really not so, but had a distinct and important bearing on the Hauraki field, *e.g.*, the "elaborate chemical disquisitions." The subject of the treatment of refractory ores—without a reference to which any paper on the Hauraki gold-fields would be very incomplete—could not be dealt with intelligently unless the question of the origin of the component parts of those ores was scientifically discussed.

Mr. Binns asked for details of alluvial deposits of Maitai age. He (Mr. Campbell) had understood that the alluvial drifts and cements from Reefton to Kumara, the Rimee and Kanisri, were either in that formation or were in a large measure derived from it. He (Mr. Campbell), however, was returning to New Zealand in a few weeks to continue his investigations into geology generally, and especially that of the Hauraki gold-field, which he regarded as being destined to occupy a foremost position in the world's gold-fields. He hoped at some time that he might be permitted to enlarge upon those matters which want of time prevented his dealing with in his paper in such a manner as he wished and as their importance deserved.

* *Trans. Fed. Inst.*, vol. xii., page 462.

DISCUSSION UPON MR. A. H. BROMLY'S "NOTES UPON GOLD-MINING IN BURMA."*

Mr. T. TRAFFORD WYNNE (Adelaide, Australia) wrote that Mr. Bromly did not refer in his paper to the very unfavourable opinions expressed by the government geologists as to the future of the Wuntho deposits, and it would be interesting to see by future developments whose opinion was correct, that of Dr. King and Dr. Noetling or that of Mr. Wright.

As regards the cost of various works, it would be seen from a paper which he had read before the Institution of Mining and Metallurgy† that

* *Trans. Fed. Inst.*, vol. xii., page 506.

† *Trans.*, vol. iv., page 292, as follows:—

In the Ruby mines district of Burma the daily pay of a coolie, whether Burman, native (of India), or Chinese Shan (here called Maingthas) is 1 rupee. Some of the best Maingtha drillers get 1·8 rupees per day, while others who drill by contract at 4 annas per foot, make up to 2 rupees per day. The best workmen are the Maingthas, who soon pick up a knowledge of how best to use a pick or a hammer, and some of the more intelligent become very useful in assisting to set timber, or in working a machine-drill. Working hours are ruled by the number of men available, 8 hours being usually the number worked, but during the five summer months the mines work 10 hours, paying the above rate.

English miners receive £20 to £30 per month, while English and Eurasian assistants are paid at the rate of from 150 to 300 rupees (say £8 15s. to £17 10s.) per month.

In all calculations of cost, the rupee has been taken at 1s. 2d. per rupee, that being about the present value.

The cost of a tunnel driven for 500 feet through a hard calc-spar rock, which when blasted fell almost to powder, its section being 8 feet by 7 feet, was as under—it being driven partly by machine-drills and partly owing to fuel being difficult to obtain, by hand labour:—

	Rupees.
For native labour	41·49
„ English miners and assistants	13·88
„ dynamite, stores, fuel, timber, etc.	25·23
Total	80·60

Or, say, £4 14s. 4d. per foot.

Another tunnel, 10 feet by 10 feet, inside timber, driven for 500 feet partly through hard gneissic rock by machine-drills, and partly through a decomposed sandy rock which disintegrated rapidly in the presence of water, of which a large quantity was met with. The part in hard rock was done very rapidly and cheaply, but in the soft ground much difficulty was experienced owing to the quantity of water and the unstable nature of the ground rendering the work of securing it with the inferior timber available very difficult and tedious. The cost was as follows:—

	Rupees.
For native labour	15·26
„ English miners and assistants	14·44
„ dynamite, stores, timber, etc.	12·52
Total	42·22

Or, say, £2 9s. 3d. per foot.

A third tunnel was driven through a heavy red clay with peaks of calc-spar rock and large boulders met with occasionally, it being 600 feet long by 8 feet by 7 feet. The cost was:—

the rates of wages and the cost of driving were both much higher in the ruby mines district than at Wuntho. He had no doubt that there was gold in payable quantities in Burma, he had seen several promising reefs, but the mining laws and regulations of the government of India were so absurd (it was the only suitable word) that there was not the slightest encouragement for any one to spend money in prospecting the country.

Mr. A. H. BROMLY wrote that he considered it unnecessary to burden the pages of the *Transactions* with a map, as the locality in question could be readily found upon reference to any modern atlas. The methods of mining adopted were doubtless primitive, but they were at the same time economical, which was the ultimate object of all such operations. To attempt to force modern mechanical appliances and methods upon unskilled labour, in a new country without local resources, and hundreds of miles from the nearest source of supply, was likely to prove disastrously expensive. As regards the methods of reduction and milling, the writer understood from the makers that this mill contained the first 6 feet frue-vanners with corrugated belts put to work. The criticism as to the duty of the stamps lost sight of the main point, which was that the duty indicated had been found to be the best commercially, after considerable trial. The mill had been run at a duty of nearly 3·5 tons per stamp per 24 hours, but with less profitable results. A stamp-mill was not

	Ruppes.
For native labour	8·86
„ English miners and assistants	12 31
„ dynamite, stores, timber, etc.	11·00
Total	32·17

Or, say, £1 17s. 6d. per foot.

Part of the best ground was driven at a contract price of 6 rupees (say 7s.) per foot for native labour only.

Two examples of the cost of excavating the rubiferous ground from the valleys, where it lies partly as large masses containing only small boulders, and in other cases amongst huge boulders of calc-spar rock, a large portion of which have to be removed before the ruby earth can be extracted, are given below. In the first case the ground extracted was 20,000 trucks, from a place where no rock was met with, and in the second 20,000 trucks extracted from amongst a quantity of huge boulders of calc-spar rock. The capacity of a truck is 15 cubic feet.

	Ruppes per Truck.
No. 1.—Labour for excavating and loading ...	0·16
„ for shunting and delivery to washer ...	0·16
English miners and assistant overseers ...	0·11
Total	0·43
Or, say, 6d. per truck of 15 cubic feet.	
No. 2.—Labour for excavating loading, shunting, and delivery to washer ...	0·44
English miners and assistant overseers ...	0·20
Total	0·64
Or, say, 9d. per truck of 15 cubic feet.	

primarily a stone-breaker. The "available natives" referred to are "natives of India." The fact of the outcrop-ores being more refractory than the pyritic prompted the putting on record of these notes, in the hope of obtaining some information upon the matter. The writer was inclined to connect the difficulties experienced with decomposition of the telluride of lead.

DISCUSSION ON MR. BRYAN DONKIN'S PAPER ON
"POWDERED COAL FOR FIRING STEAM-BOILERS."*

The PRESIDENT said that mechanical stokers had been introduced at some of the collieries under his charge, and it had been found very beneficial to break the inferior coal used (containing as much as 30 per cent. of ash) into small nuts. It was possible in this way to use splint coal which could not otherwise be properly consumed.

Mr. J. H. MERIVALE (Broomhill) said that mechanical stokers wore out very rapidly owing to the impracticability of lubrication, and although very effective when new, they soon deteriorated from this cause.

Mr. A. L. STEAVENSON (Durham) said that he had inspected the Wegener apparatus described in Mr. Donkin's paper, and it appeared to give excellent results; he could not say whether it was economical or not—probably it was, but it occurred to him that the cost of crushing the coal might neutralize its other economies.

Mr. BRYAN DONKIN wrote that since the reading of his paper, there had been many applications of the Wegener system on the Continent. At Berne, in Switzerland, some very complete tests had been made, showing a large economy over a boiler with the ordinary grate, and with practically no smoke. At Paris, during the last month, tests had been made on a boiler supplying steam to a pumping-engine. The reports had not yet been published, but they were said to be very satisfactory, the object of the municipality being to make tests on the best practical methods now known for diminishing smoke to a minimum.

The following paper by Mr. Th. Lichtenberger on the "Honigmann System of Boring and Sinking Shafts" was read:—

* *Trans. Fed. Inst.*, vol. xi., page 321; and vol. xii., page 207.

HONIGMANN SYSTEM OF BORING AND SINKING SHAFTS.

By TH. LICHTENBERGER.

The Honigmann method (Plate VI.) depends on the application of a higher pressure of water in the borehole or shaft in order (1) to sustain the sides, and (2) to raise uninterruptedly the bore-slush.

The higher water-pressure is produced (1) by making a water-level in the interior of the borehole or shaft, which surmounts the natural water-pressure in the strata, (2) by applying a thick liquid in the interior, produced by adding clay to water, and thus increasing the specific gravity of the liquid to 1.200. The sustaining of the sides depends on the fact that the running sand can form a vertical side if no power be acting against it. The water-pressure in the strata behind the sides of the shaft is the power which makes the sand run. This power is compensated by the higher water-pressure produced in the aforesaid manner.

The admixture of clay with water has the purpose also of compacting the sides by the clay penetrating to a certain distance, thus preventing the passage of water from the interior of the shaft into the surrounding strata.

The raising of the bore-slush depends on the theory of the syphon. The syphon is formed by the rotating hollow boring-rods, which are connected by a revolving arrangement with a short horizontal pipe. The latter is provided with a leather pipe, which discharges itself into a box.

By the higher water-level, and the water-pressure in the borehole or shaft, the bore-slush is pressed from the bottom into the boring-rods, and thence into the box. For the raising of the bore-slush, the water-level in the shaft must be higher than the horizontal discharge pipe and higher than is necessary generally for the sustaining of the sides: the higher pressure in the borehole or shaft is, however, produced without changing the water-level—which is sufficient for the sustaining of the sides—by forcing air through a central tube into the boring-rods, and forming a mixture in the boring-rods of air, water, and slush, which has a less specific gravity than the water mixed with clay in the borehole or shaft.

The method is applied in the following manner:—At first one sinks, according to the ordinary method, a shaft to a depth of 30 to 60 feet

below the water-level, in order to stop the upper gravel strata, and to form a solid guidance for the boring-rods. After that one erects the arrangement represented in Plate VI. *a* is the boring-mandril, which is hanging from the hoop and plate *b*, the friction, caused by its rotation, being diminished by the four pulleys *c c*. The hoop and plate *b* is attached to a rope, which is wound round a winch, and lowered by a workman as the boring-rods descend downwards. The boring-mandril *a* passes through the wheel *d*, which is driven by the teetted wheels *e, f*, and *g*, the bevel-wheel *g* being driven by the fast pulley *h* driven by a steam-engine. The driving-wheels *d, e*, and *f*, are attached to the boring carriage *i*, which can be removed on rails if the boring-rods are to be raised, and for that purpose a steam-windlass is provided.

The boring-mandril *a* carries hollow rods *k*, to which the revolving arrangement *l* is attached, *s t* is the boring tool, *m* is the sunken tubbing-cylinder formed by strong riveted-iron sheets, the bottom of which reaches underneath the natural water-level. *r* is the tube supplying compressed air, produced by a small engine, *n* is the horizontal pipe, *o* the leather pipe, *p* the box, and *q* is the basin for the supply of water mixed with clay. The raised water is used again for this purpose.

The method has been applied successfully in sinking two shafts in the Oranje-Nassau coal-field, near Heerlen, in Holland, one of them being sunk through 200 to 250 feet of running sand.

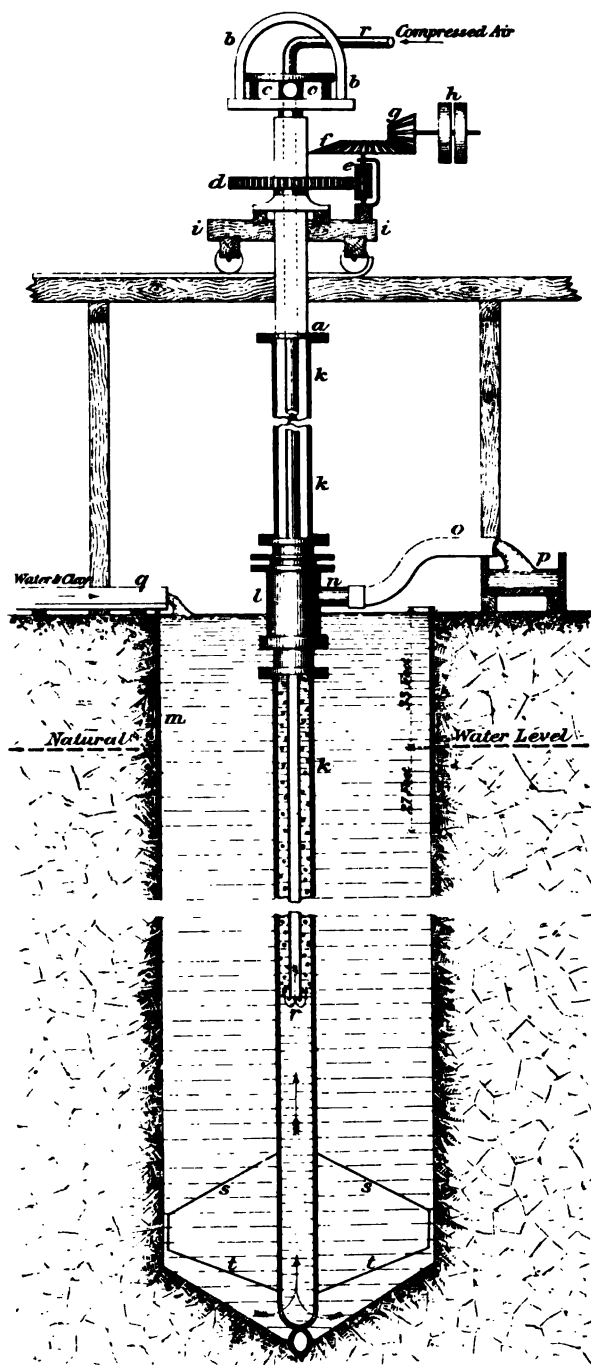
The PRESIDENT remarked that the system described seemed to be very similar to the Kind-Chaudron system, except in regard to the method of removing *débris* from the bottom of the pit.

Mr. W. COCHRANE (Newcastle-upon-Tyne) asked whether any sinking by this method had been done through hard rock, or was it only intended for sinking through soft clay or running sand?

Prof. H. LOUIS (Newcastle-upon-Tyne) wrote that at Heerlen, in Holland, the sinking of two shafts was commenced by the Honigmann system. He had read in a recent number of the *Oesterreichische Zeitschrift für Berg- und Hüttenwesen** that the first shaft had to be abandoned at a depth of about 230 feet, and that the second shaft was stopped after reaching a depth of about 180 feet, about two and a half years after the commencement of operations. Opinions differed as to the reasons for

* 1897, vol. xlv., page 145.

To illustrate M. Th. Lichtenberger's Paper on the Honigmann System of Boring and Sinking Shafts.



the failure, many engineers maintaining that the system employed was worthless, as, in spite of all exertions, no progress could be made. Possibly, when the details have been thoroughly worked out by long and costly experience, the system may prove successful.

Mr. W. C. BLACKETT (Durham) remarked that it was surprising to find that the motive power for raising the stuff excavated appeared to depend on the difference in specific gravity between the water in the pit and the mixture of water and air in the elevating-pipes. It was difficult to conceive that so small a difference could lift such a quantity of stuff as was represented.

Mr. COCHRANE asked whether it was a fact that the whole of the sinking material from the bottom of the shaft was carried through the central tube to the surface.

Mr. M. WALTON BROWN said that from papers by Mr. W. Schulz * and Mr. A. Habets † he found that two pits were being sunk by the Honigmann system in the Oranje-Nassau concession, near Heerlen, in Holland. The strata had been proved by a borehole as follows :—

	Ft.	Inch.
Clay	29	6
Clay and sand	6	7
Sand and gravel	4	6
Sandy clay	0	7
Grey sand	29	4
Argillaceous sand	17	0
LIGNITE	2	6
Black clay	1	2
Grey clay	9	5
Brown sand	8	2
Grey sand	1	9
Grey micaceous sand	31	2
Fine sand	1	0
Greenish sand	8	10
Argillaceous clay	35	6
Greenish sand	3	3
Argillaceous sand	31	6
Total	221	9
Calcareous marl, in hard and argillaceous beds	48	0
Total	269	9

No. 1 pit, 8 feet in diameter, was sunk to the calcareous marl in 1894 by the Honigmann system, and a sheet-iron lining, similar to that of the

* *Glückauf*, 1895, vol. xxxi., page 1277.

† *Revue Universelle des Mines*, etc., 1896, vol. xxxiii., page 329.

Kind-Chaudron system, was inserted; but, owing to various accidents, the connexion with the marl had not been completed. A recent boring had shown that the marl contained a bed of quicksand 1 foot thick, holding water under pressure, and rising to within 46 feet of the surface.

Sinking through quicksand without a lining was the characteristic feature of the Honigmann system, and the other feature was the continuous removal of the *débris* to the surface, without raising the tools.

In sands, the boring-tool consisted of a trepan made of channel iron, whose edges were replaced by steel-knives, thus forming a grinding or abrading-tool whose diameter was the same as that of the shaft. The shaft of the trepan was a hollow cast-iron pipe $5\frac{1}{4}$ inches in diameter and 1 inch thick. This shaft was fastened, at its upper flange, by bolts to the ordinary hollow boring-rods $5\frac{1}{4}$ inches in diameter, made of wrought-iron 0.35 inch thick, in lengths of 13 feet, which were bolted together by wrought-iron flanges. Short lengths of rods, from 3 to 6 feet long, were also used as required.

The trepan was rotated by gearing and belting from a small engine, and was lowered by a rope as the sinking became deeper.

At Heerlen, water was found at a depth of 33 feet from the surface; and after the shaft was sunk and timbered to this depth, the wrought-iron tubing, 0.59 inch thick and $12\frac{1}{4}$ feet in diameter, with cutting-edge, was lowered to a depth of 59 feet. The water-level inside the cylindrical tubing was kept at surface-level, so as to create a pressure from the pit into the strata, and this pressure of 33 feet was increased by charging the water with clay, so as to increase its density.

In March, 1896, the No. 2 shaft had reached a depth of 197 feet, the density of the muddy water was 1.20, the outward pressure of 33 feet was increased to 39.6 feet, and at the bottom of the shaft there would be an outward pressure of about 2 atmospheres (30 pounds per square inch). The sandy sides of the shaft were maintained in a vertical position without lining, owing to the outward pressure and to the cementation of the sands produced by impregnations of clay from the muddy water. This cementation of the sand was said by Mr. Honigmann to extend to a distance of $2\frac{1}{4}$ to 3 feet.

The excavated material was continuously removed to the surface through the central pipe of the boring trepan. At first, a pump was employed, but at present a jet of air was forced by means of a small pipe into the central tube, and the air mixing with the water, diminished the density of the water in the central tube, and the water charged with sand and clay was discharged upwards to the surface. The water was led

from the shaft into subsiding-tanks, where the sand was deposited. The clear water was then returned to the shaft so as to maintain the level of the internal water at the surface. Additional water and clay was also supplied so as to maintain the water-level and the density of the shaft-water at 1.200.

It was intended to sink through the calcareous marl by the same system, the cutters being replaced by steel rollers with helicoidal cutting-edges, fastened to a sheet-iron trepan.

The lining of the shaft will be made by cylindrical descending-tubbing 12 feet in diameter, with a cutting-edge, and equilibrium water-column. This lining will leave a space of about 3 inches for concrete-backing.

A vote of thanks was accorded to the writer of the paper.

The following "Notes upon Foreign Mining Laws and Adequate Areas for Mining Concessions" by Mr. H. D. Hoskold was taken as read :—

NOTES UPON FOREIGN MINING LAWS AND ADEQUATE AREAS FOR MINING CONCESSIONS.

By H. D. HOSKOLD.

It appears to be impossible to offer any evidence to prove that, in ancient times, the law initiated a mining industry; on the contrary, when mining became identified as a profitable occupation, and conflicting interests arose, the force of necessity, sense of security and convenience, required that certain dispositions of law should be introduced, such as were considered adequate to regulate and settle questions of disputed rights in mining matters; but it would be difficult to determine how, when, and where any such mining laws were first introduced.

As may have been anticipated, progressive ideas and custom produced various changes in the law of mines until, during the last twenty-five years, legislative intervention has remodelled, in an extraordinary degree, the entire administrative system of extracting minerals from the mines; so much so is this the case in Great Britain, that mining is now subject to the intervention of very high class legislative control.

Such measures do not, however, touch or regulate the original rights of the owner of the soil—probably where mining rights are involved it would be better if they did—but deal more particularly with the form or manner in which minerals may be extracted from the mines with the greatest safety to human life.

Were we to urge the importance and freedom, which common and equitable rights of the subject imply, in an absolute manner, we may be tempted to conclude that the time is not far distant when a point will be reached where government restrictions of private property should cease, unless, indeed, it could be proved demonstratively that extended legislative measures would be compatible with particular interests, and conduce to the general benefit of the community more than at present. However, this is a very broad and difficult question, from which arguments may be deduced cutting both ways.

The conditions of mining leases, royalties, railway tariffs, and general taxes are primary elements of great importance, requiring much consideration and judgment in their settlement, because they affect the

benefit to be derived from mining in Great Britain to a very considerable extent. Taken in connection with the immense capital sums invested in mining, fluctuations in trade, as also difficulties of the labour market, the question could hardly assume a more serious aspect. In a word, the whole of these things constitute a burden occasioning no small amount of anxiety in reference to the amount of annual dividend to be obtained from the exploitation of mines.

The inconvenience of a general code of mines to meet present needs and future contingencies has not been forced upon the British mining public; but, in Latin countries, the case is different, and it is to the mining codes of the South American republics, especially that of the Argentine Republic, to which the writer desires to direct public attention.

However, he does not possess any evidence fixing the date when mining rules, regulations, and laws were first enforced in Europe; but, from information, recently received, he is led to conclude that it is highly probable that the Romans possessed some such rules for guiding the mining operations which they carried on in Spain and Portugal.

The tin-mines, in Cornwall and Devon, appear to have belonged to the Crown, and to have been worked from a very remote period, and were "guided by special laws, customs, and by prescription, time out of mind."* An authoritative document exists upon the subject of the Stannaries, *i.e.*, *Carta Stannariarum*, King Richard I., 1198, by which he received royalty from the tin-mines.†

The charter of King John, 1202, and King Edward, 1305, confirmed the stannary customs and their high antiquity.‡

Crown mines were exploited in various parts of England and Wales in the time of King Edward I., between 1272 and 1296, and successive kings granted licences and patents for the same object, receiving royalty at the rate of from the "twelfth to the fifteenth part of the fine gold and silver," and the lord of the soil the twentieth part; but the crown did not always control the latter rate.

Queen Elizabeth conceded to two Germans the right to exploit mines in "eight counties, and in Wales, receiving a royalty of a tenth part of all gold and silver ore holding and yielding 8 pounds weight of clean gold and silver or upwards in every hundredweight." §

* *Lord Coke: 4 Inst.*, page 229.

† *Harrison's Laws and Jurisdiction of the Stannaries in Cornwall*, 1835, page 6.

‡ *Ibid.*, page 6.

§ *Some Account of Mines and the Advantage of them to the Kingdom, relating also to the Mining Adventurers*, 1707, page 13.

In 1568, Queen Elizabeth conceded all the minerals, not previously included in the first concession of the eight counties, to a second party of mining adventurers, including the "English Pale in Ireland," receiving royalty at the rate of "8 pounds weight of fine gold, and for silver, the twentieth part for every hundredweight of gold ore."*

In a lawsuit between Queen Elizabeth and the Earl of Northumberland, in 1568, it was held that, "although Henry VIII. had granted the estate of Kenswick to the earl, with all mines within the said manor, yet the mines could not pass; and that though the grant of the manor was good, yet the king could not alienate mines as being things perfectly linked to the prerogative of the crown; and that notwithstanding his grant, the queen had power to dig and search for metals and treasures in any man's ground."†

The lead-mines of Derbyshire were exploited under a code of 59 rules in 1668,‡ and those of Dean Forest also at a very early date, "time out of mind."

In Spain,§ the mines were claimed by the crown as early as 1256, and the law seems to have been first introduced in 1887.

The mining laws known as "ordenanzas de mineria de Mejico," were the result of various communications made by the viceroy from 1771 to following dates, to the King of Spain, and|| finally in 1788, commenced to be employed in the Spanish American colonies.

Some of the dispositions in this code were modified up to 1844; but, as a whole, it has remained in force in the Argentine Republic for a period of 104 years,¶ or until 1887.

Article I. of Title V. of the old code is important as defining the original right of the king to possess South American mines. The text is as follows, "The mines (constitute) a property of my royal crown, as also by virtue of their nature and origin (acquired by conquest) . . . and, without separating them from my royal patrimony, I concede to my vassals (subjects) in property and possession in such a manner that

* *Some Account of Mines and the Advantage of them to the Kingdom, relating also to the Mining Adventurers*, 1707, page 14.

† *Ibid.*, page 14. The Earl of Northumberland's case. *Plowden's Reports*; Walmsley, *Mining Laws of the World*, 1894, page 20.

‡ *Houghton*, 1630-1738, pages 1-32.

§ Walmsley, *Mining Laws of the World*, 1894, page 129.

|| *Ordenanzas de Minería de Mejico*, edition 1881, page 214.

¶ *Código de Minería de la República Argentina*, edición oficial, 1887.

they may sell, permute, lease, will, and mortgage the rights which they possess in them under the same terms of possession" *

The conditions are thus stated in a contracted form :—"The concession is granted under two conditions ; the first is the contribution to my royal treasury (3 per cent. of the value of the gold and silver extracted) † and, the second consists in working the mines continuously, with 4 miners in each, or, in default to do so for 4 consecutive months, entail forfeiture."

Prior, and up to 1771, common and equitable rights in mining matters were not so well understood and applied in Spain and South America as at present.

The old code of Spanish mining laws must, therefore, have been considered a masterpiece, and, consequently, adequate to the exigencies of mining at that period, when the produce of the mine was measured by a few arrobas, ‡ or quintales § of mineral per day, and not hundreds of tons as in the case in Great Britain to-day.

Analysed by the light which we now possess, the old code is full of incongruities. Nevertheless, the general principles of various of its dispositions form the basis of nearly every modern mining code in South America.

Titles of mining concessions, leases, etc., would involve various general conditions, including time of duration, royalty, etc. In Europe, especially in Great Britain, all such conditions are regulated between interested parties as each particular case arises ; but, in the Argentine Republic, such elements as those indicated involve many collateral legal dispositions, all of which are contained in 372 articles, which form the present mining code.

To discuss the merits of these laws in a consecutive order, and the laboriously appended commentaries, or doctrines of law, as well as the contents of various other South American mining codes, would occupy more space than could be conveniently allowed for a single paper. It is, therefore, proposed to treat in a partial manner the important question of area or extension which should be assigned to concessions of various classes of metalliferous-ore veins, and economic mineral substances, leaving it open to treat other questions of mining law in a future paper or papers.

* *Ordenanzas de Minería de Mejico*, edition 1881, page 68.

† *Ibid.*, page 164.

‡ 1 Arroba is 25 lbs.

§ 1 Quintal is 100 lbs.

Previous to entering upon foreign practice, now some twenty years past, the writer was not aware that any particular rules were generally applied in determining the area of mining concessions upon principles which should have a strict relation to the amount of capital required for a mining installation, exploitation, annual output, duration, and probable profit to be derived. Doubtless a proper and absolute solution of such questions, under all circumstances, would, to a very considerable extent, be surrounded with difficulties; but it would be too much to make a sweeping assertion that such points have not been considered and approximately correct data derived. However, there is no evidence available proving that in South America the areas of mining concessions, as indicated in the mining codes of the various republics, have been assigned with reference to scientific, equitable, or commercial principles.

The old law, or *Ordenanzas de Minería* assigned for concessions of metalliferous veins 200 varas,* or 550 feet, for the length along the vein, or in direction of, or parallel to, the line of its outcroppings, the width of the concession being determined by the amount of the angle of declivity of the mineral vein. The angle of declivity was originally ascertained by letting a plumb-line fall from a point in the hanging-wall of the mineral vein to a depth of 1 vara, or 33 English inches, as the unit of measure, and measuring the base of the triangle, or distance from the termination of the plumb-line to the vein of mineral, by so many *palmos y dedos*, or palms and fingers, as the case may have been. These measures were then compared with those of the legal scale of the *Ordenanzas de Minería*, and the corresponding width of concession selected and measured upon the ground. For example, for two palms and three fingers the width was 112.5 varas, or 309.375 feet, and proceeding by three fingers at a time, until four palms were reached, supposed to give an angle of 45 degrees, with a corresponding width for the concession of 200 varas, or 550 feet.

About 1844, angles of declivity, corresponding to the right-angled triangles formed by the palms and fingers, were added to the old legal scale of the *Ordenanzas*.†

All the metalliferous veins and economic mineral substances existing under the superficial rectangular area of 40,000 square varas, or 302,500 square feet, and included between perpendicular planes falling from each side of the rectangle and passing towards the centre of the earth, until the mineral veins were intersected, would form and belong to a *per-tenencia*, or mining concession.

* *Ordenanzas de Minería* (1783), 1881, page 91. † *Ibid.*, page 275.

The first column in Table I. contains the *Ordenanza* scale of angles, previously referred to, under which mineral veins were supposed to exist. The other five columns contain calculated data, including the three sides of a corresponding series of right-angled triangles. The

TABLE I.

Scale of Degrees of the <i>Ordenanzas</i> for Mining Concessions.	Secants corresponding to the Angles in Column (1).	Widths given in the <i>Ordenanzas</i> for Mining Concessions.	Lengths of Mineral Veins or Hypothenuses corresponding to the Angles in Column (1), and data in Column (3).	Sines of the Angles given in Column (1) for the Declivity of the Mineral Veins.	Depths or Perpendiculars calculated corresponding to the Angles in Column (1), and Widths of Concessions in Column (3).
FIRST SERIES CALCULATED FROM THE <i>Ordenanzas</i> .					
Degr. Mins.		Varas.	Varas.		Varas.
45 00	1.41422	200.0	282.84400	0.70711	200.0018
46 51	1.46218	187.5	274.15875	0.72957	200.0180
48 49	1.51867	175.0	265.76725	0.75261	200.0191
50 54	1.58559	162.5	257.65837	0.77605	200.0018
53 8	1.66681	150.0	250.02150	0.80003	200.0247
55 30	1.76551	137.5	242.75763	0.82413	200.0638
58 00	1.88708	125.0	235.88500	0.84305	200.0423
SECOND SERIES CALCULATED FROM THE <i>Ordenanzas</i> .					
60 00	2.00000	100.0	200.00000	0.86603	173.2060
65 00	2.36620	100.0	236.62000	0.90631	214.4511
70 00	2.92380	100.0	292.38000	0.93969	274.7466
75 00	3.86370	100.0	386.37000	0.96593	373.2064
80 00	5.75870	100.0	575.87000	0.98481	567.1225
85 00	11.47370	100.0	1,147.37000	0.99619	1,142.9985
89 00	57.29860	100.0	5,729.86000	0.99985	5,721.0005
(1)	(2)	(3)	(4)	(5)	(6)

hypothenuses in column 4 form the lengths of the mineral veins. Table I. is divided into two parts, i.e., the first ranges from 45 to 58 degrees, with a width of concession from 200 to 125 varas, or from 550 to 343.75 feet. The length of the mineral veins, in direction of the declivity, is from 282.844 to 235.885 varas, or from 777.82 to 648.68 feet. The depth remaining constant at 200 varas, or 550 feet. In the second part, the angles of declivity range from 60 to 89 degrees, the width of the concession remaining constant at 100 varas, or 275 feet, and the corresponding length of the mineral veins ranges from 200 to 5,729.86 varas, or from 550 to 15,757.113 feet, and from 173.206 to 5,721.0005 varas, or from 476.316 to 15,732.75 feet in depth, or 2.97 miles.

It is apparent that no rule could have been applied in the formation of this antiquated legal scale assigning lengths of mineral veins impossible of exploitation under past, or, indeed, present conditions and circumstances in South America.

Fig. 1 (Plate VII.) is a graphic representation of mining concessions corresponding to the legal scale of angles of the *Ordenanzas de Minería*, giving the dimensions as found in Table I. Fig. 1, as well as the contents of Table I., show the ill-proportion which existed between the length of the mineral veins in direction of their declivity and the depth to which they extended.

The legal scale determining the widths of mining concessions in Chili up to 1888 was similar to that of the *Ordenanzas de Minería*.

Fig. 2 (Plate VII.) is a geometrical representation of the concessions contained in that scale.

With the object of determining the length of mineral veins in the direction of the declivity, which should be in proportion to the increased depth, labour, and cost of installation and exploitation, the data in Table II. have been calculated.

TABLE II.

Inclination.	Hypotenuses or Lengths of Mineral Veins.	Bases of the Triangles.	Perpen- diculars or Depths of Veins.	Weights to be Balanced or Raised.	Powers necessary to Balance Weights in Column (5).	Difference of Powers or Ratios between the Consecutive Numbers in Column (6).
Degrees.	Metres.	Metres.	Metres.	Quintals.	Quintals.	
30	100	86·60254	50·00000	5	2·50000	0·000000
35	100	81·91520	81·35764	5	2·86788	1·147150
40	100	76·60444	64·27876	5	3·21393	1·120660
45	100	70·71068	70·71068	5	3·53553	1·100070
50	100	64·27876	76·60444	5	3·83022	1·083350
55	100	57·35764	81·91520	5	4·09576	1·069330
60	100	50·00000	86·60254	5	4·33012	1·057220
65	100	42·26183	90·63078	5	4·53153	1·046510
70	100	34·20201	93·96926	5	4·69846	1·036840
75	100	25·88190	96·59258	5	4·82962	1·027920
80	100	17·36482	98·48078	5	4·92403	1·019550
85	100	8·71557	99·61947	5	4·98097	1·011560
89° 50'	100	0·29089	99·99998	5	4·99999	1·003818
Perpendicular. 90°	Perpendicular. 100	0·00000	100·00000	5	5·00000	1·000000
(1)	(2)	(3)	(4)	(5)	(6)	(7)

The veins of mineral have been considered as a series of inclined planes under the angles of declivity indicated in column (1), and commencing at 30 degrees. In column (2) the unit of measure, or length of the mineral veins or hypotenuses, is taken at a constant of 100 metres. Column (3) contains the bases, and column (4) the perpendiculars or depths of the mineral veins.

Column (5) represents the constant weight of 5 quintals, or 500 lbs., to be balanced upon the veins or inclined planes in column (2) by a counter-balance at surface.

Column (6) contains the counter-weight required to balance the weight indicated in column (5) upon the planes in column (2); and column (7) contains the difference or ratio between the powers in column (6).

To adjust the final result with mathematical precision, friction and the force necessary to give motion and a required speed may be added corresponding to each angle of declivity; but, as it is only intended to give an illustration of approximate correct results, the latter elements have been neglected.

In Table III. it is proposed to form a scale commencing with a vein of mineral having a declivity of 30 degrees. This angle would give a mineral vein of 230·94 metres in length at a depth of 115·47 metres, and a width of concession of 199·9999 metres, or, practically, 200 metres.

TABLE III.

Inclina- tion.	Hypothenuses or Lengths of Veins.	Perpendiculars or Depths of Veins.	Bases of Triangles or Widths of Concessions.
Degr.	Metres.	Metres.	Metres.
30	230·94000	115·47000	199·99990
35	264·92282	151·95347	217·01206
40	296·88840	190·83618	227·42969
45	326·59802	230·93968	230·93968
50	353·81996	271·04179	227·43108
55	378·35029	309·92639	217·01279
60	399·99949	346·40971	199·99974
65	418·60346	379·38358	176·90948
70	434·02481	407·84990	148·44520
75	446·14278	430·94082	115·47022
80	454·86487	447·95447	78·98646
85	460·12310	458·37219	40·10235
89° 50'	461·87984	461·87790	1·34356
(1)	(2)	(3)	(4)

The declivity of the second mineral vein in the scale is 35 degrees; and considering, as previously intimated, that more power is required to balance 5 quintals, or 500 lbs., with extra cost, than would be the case upon an inclined plane of 30 degrees, the mineral vein should have a greater or a proportional length to compensate for the difference.

The first ratio in Table II., derived from column (6), is $(2·86788 \div 2·50000 =) 1·147150$. The length of the first mineral vein in column (2), Table III., is 230·94000 metres, and this length of vein, multiplied by 1·147150 the ratio, gives 264·92282 metres for the length of the second mineral vein under the proposed conditions, with a width for the concession of 217·01206, and depth of 151·95347 metres respectively. The excess in length of the mineral vein, due to the principle involved, is 33·98282 metres. The other ratios contained in column (7) of Table II. are treated successively in the same manner, until, finally, we have a

length of mineral vein (derived from $4.99999 \div 4.98097 = 1.003818$, which multiplied by 458.37219) of 461.87790 metres contained in column (8), Table III., under a declivity of 89 degrees 50 minutes, which is only 10 minutes from the perpendicular.

It would be excessively difficult to frame a project for the determination of the area which mining concessions should have according to the conditions laid down, or those required, which would be absolutely free from objection, imperfections, and not liable to adverse criticism; nevertheless it is submitted that the system now proposed—whatever value it may have—is, at least, original, based upon well-founded principles, and better adapted for the object under consideration than the antiquated methods which have been followed for so many years, and are now under discussion.

It will be observed that in column (2), Table III., there is a regular increase in the length of the mineral veins, as there should be, according to the excess of depth, work, and expense of installation and exploitation.

Fig. 3 (Plate VII.) is a geometrical representation of the calculated quantities contained in Table III. It shows the measure of all the concessions which could exist under the scale of angles proposed; in fact it forms a series of cross sections of mineral veins, including depth, angles of declivity, etc.

Fig. 3 is more uniform in character, and presents a more harmonious curve of work than exists in Table I. and Figs. 1 and 2.

The Argentine mining code of 1878, still in force, contains a similar scale of angles and width for concessions to that of the *Ordenanzas de Minería*. It commences with an angle of 45 degrees, and width of concession of 200 metres, proceeding to 75 degrees; and for this, and all higher angles, the width of concessions is 300 metres. The author of this *Código* has fallen into the error of referring the angles of declivity of the mineral veins to the vertical instead of a horizontal line, and it may be dismissed without further comment.

To fix an area for the concession of a mine to contain just such a quantity of mineral and no more than is sufficient to give an estimated extraction or produce per annum for a definite period, having special reference to the cost of installation, exploitation, contingencies, and various other collateral and important questions, would involve very serious consideration as well as some difficulty; still, when it is necessary to form a code of mining laws to contain legal dispositions to meet all imaginary or real cases before hand, the best experience and methods

should be invoked for the formation of a legal scale of areas for mining concessions, rejecting such antiquated modes as we have discussed.

For the determination of the length of auriferous quartz-mining concessions, measured in the direction of, or parallel to, the outcroppings of the mineral veins, the following notes would be required, *i.e.*, length of the mineral vein in the direction of its declivity, as previously determined, say, 231 metres; thickness of mineral vein, 0.75 metre; working days per annum, 240; duration of mine, 23 years; extraction of mineral, 60 tons per day; specific gravity of mineral, 2.5, and weight per cubic foot, 156 lbs.

Then we should have $231 \text{ metres} \times 0.75 \text{ metres} = 173.25 \text{ cubic metres}$, or 6,109 cubic feet. And $6,109 \text{ cubic feet} \times 156 \text{ lbs.} \div 2,240 \text{ lbs.} = 425 \text{ tons}$, or the quantity of mineral existing in the mineral vein in the direction of the declivity, with one metre of length measured in the direction of the line of outcroppings. Also $240 \text{ days} \times 60 \text{ tons} \times 23 \text{ years} \div 425 \text{ tons} = 775 \text{ metres}$, or the length of the concession required.

In a similar manner, varying the data according to the necessities of the case, the length of mining concessions for any other class of mineral may be ascertained.

For example, the length of a silver-mining concession is, according to the same rule, determined to be 464 metres, a copper concession 349 metres, a galena mine 416 metres, an iron mine 493.6 metres, and a coal-mine 2,984 metres in length respectively.

The Argentine legal scale assigns 300 metres in length for the first four classes of mines previously indicated; but for an iron-ore or coal-mining concession, the area is 180,000 and 270,000 square metres, or 171.97 and 257.95 acres respectively; but the area proposed in the scale of the writer for an iron-ore and coal-mining concession is 98,720 and 596,800 square metres respectively.

The area for a coal-mine, as assigned by the code, is, therefore, much too small; but that for an iron-mine is too great.

The writer has estimated that the proposed area for an iron-mine should contain sufficient ore to supply two small blast furnaces making 200 tons of ingots each per week for twenty-three years, and the area of the coal-mine is estimated on the assumption that 200 tons per day would be extracted.

In Great Britain, this would be an insignificant quantity; but, in a new country like the Argentine Republic, where industries and markets have to be created, it would, undoubtedly be sufficient, because, under such circumstances, it is not probable that each coal-mine in the republic,

capable of yielding 200 tons per day, would be exploited simultaneously. The same remark applies to iron-ore mines, and the erection of a small establishment for each.

Mines of silver, copper, galena, etc., have been subjected to the same principles with reference to the legal areas of each. Mines which are not capable of fulfilling such conditions as those proposed ought, at least for the present, to be considered too poor to yield an adequate profit.

Metalliferous veins are very irregular both in thickness and declivity ; and are not parallel in their formation for any great distance like coal-seams, and, for this reason, the best formed rules must frequently fail to give absolutely accurate results ; still, as it is a legal necessity to sink pits (*pozos de ordenanza*) a few metres in depth upon mineral veins before concessions are given, a fairly good opinion may be formed as to the probable contents and capacity of yield of the mineral veins ; besides, in most of the South American republics, some of the mines have been worked to a considerable extent, and, for that reason, a certain amount of experience exists as to the general behaviour of metalliferous veins. Nevertheless, the question is complex.

It may be further remarked that the application of the formulæ now proposed in these notes, gives a more rational area for the concession of a mine than has hitherto been assigned by the Argentine mining code.

Frequently it happens that more than a single vein of mineral exists in small superficial areas, and if concessions were to continue to have a definite width assigned to them, as at present, such additional veins would be included in a legal concession. The system proposed would, in the opinion of the writer, under any circumstance, confer greater advantages than are at present realized.

Areas of various other metalliferous and economic mineral substances are assigned in the Argentine mining code, including auriferous deposits or superficial gold-washings, the latter of which we now propose to consider.

When gold was first discovered in Australia, each miner was allowed 144 square feet for his mining claim ; but, when the superficial deposits were more or less exhausted, and deeper and more formal mining became a necessity, the area was extended to suit the conditions.

In the Argentine Republic, auriferous gold-washings or deposits have not hitherto been discovered to be so rich as those formerly existing at the commencement of the gold mania in Australia and California. How-

ever, the Argentine mining code assigns 100,000 square metres, or 95·58 acres, for a concession of this class; but whether this area is in excess or defect of the proper quantity, must depend upon the depth of the auriferous deposit from the surface, its thickness upon the bed-rock, richness or capacity of yield, facilities for exploitation, resources of the locality, as well as cost of installations and exploitation, etc., and, without a prolonged and proper study of each auriferous mining district, it would be exceedingly difficult to assign a proper area, for it is certain that, as the condition of each mining district would differ, a constant area could not be equitably fixed for all the concessions.

Assuming that an efficient system of hydraulic mining were intended to be introduced, it would be necessary to determine the data contained in the following notes with the greatest amount of accuracy:—*i.e.*, (1) capital required for installation, say, £20,000; (2) yearly expenses for exploitation, £5,000; (3) average thickness of auriferous deposit, 2 metres; (4) average yield of auriferous deposit per cubic metre, 0·052093 ounce; (5) interest expected upon capital, 59 per cent. per annum; (6) duration of the concession, 10 years; and (7) gross selling price of gold produced, £3 10s. per ounce.

Then we should have $£20,000 \times 59 \text{ per cent.} = £11,800$ gross estimated income per annum, and $£11,800 + £5,000 \div £3 \text{ 10s.} = 4,800$ ounces of gold required to be extracted from the mine per annum. Also, $4,800 \text{ ounces} \times 10 \text{ years} \div 0\cdot052093 \text{ ounces per cubic metre} = 92,142\cdot9$ metres, or the length required for the concession, with 1 metre of width; but as the auriferous deposit is estimated at 2 metres in thickness, we also have $92,142\cdot9 \div 2 = 46,071\cdot45$ metres in length.

Naturally, the concession could have any form to contain that area, depending upon the topographical features of the ground, as also the rights of other legal claimants for concessions in the same neighbourhood.

If the data previously indicated were to be varied—as probably would be the case after a proper study of the ground had been made—the final results to be deduced would differ, as is evident from an inspection of the contents of Table IV.

It is evident that 100,000 square metres, as assigned by the Argentine mining code, constitute too small an area when the yield of auriferous deposits varies from 0·0260465 to 0·052093 ounces of gold per cubic metre, and the capital for installation, annual exploitation, and the other conditions were to be as previously indicated. It is also to be presumed that no formal company could be found willing to accept a mining negociacion or concession under such conditions. On the contrary,

TABLE IV.

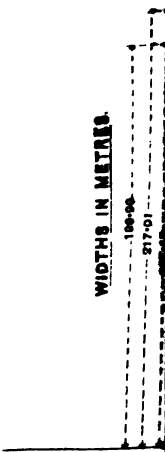
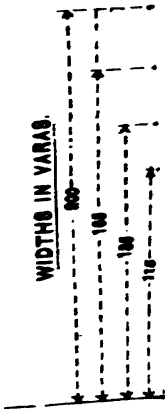
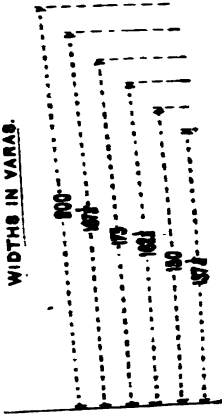
Unit of Duration of the Concession, 1 Year.	Cost of Installation.	Average Thickness of the Auriferous Deposit.	Percentage Required upon the Capital.	Estimated Gross Income.	Annual Cost of Exploitation.	Yield of Gold per Cubic Metre.	Selling Price of Gold per Ounce.	Calculated Area of Concession for 1 Year's Working.	Calculated Area of Mining Concession Required for 10 Years' Working.
Days.	£	Metres.		£	£	Ounces.	£	Square Metres.	Square Metres.
240	20,000	1	59	11,800	5,000	0.0520930	3.5	92,142.90	921,429.0
240	20,000	2	59	11,800	5,000	0.0520930	3.5	46,071.45	460,714.5
240	10,000	1	59	5,900	5,000	0.0520930	3.5	59,783.08	597,830.8
240	10,000	2	59	5,900	5,000	0.0520930	3.5	29,891.54	298,951.4
240	10,000	1	59	5,900	5,000	0.0260465	3.5	119,566.16	1,195,661.6
240	10,000	2	59	5,900	5,000	0.0260465	3.5	59,783.08	597,830.8
240	6,000	1	59	3,540	3,000	0.0260465	3.5	71,739.38	717,393.8
240	6,000	2	59	3,540	3,000	0.0260465	3.5	35,869.69	358,696.9
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

100,000 square metres for an auriferous mining concession would be an excessive quantity for an ordinary or common miner with three or four associates, working and extracting the gold in an antiquated form, and with a very small amount of capital. As the law stands at present, any person without visible means to exploit a mine may obtain a mining concession, and such a concession may pass from one to another and benefit be obtained by a simple transference of documentary rights, without improving or developing the mining concession, supposing the legal number, *i.e.*, three miners, are employed upon such concessions for 300 consecutive days in each year.

The difference of area indicated in column (10) Table IV., proves that the extent of mining concessions should be adjusted to suit conditions and circumstances as may arise, and, for this object, it would be convenient to define by a special legal disposition in any future mining code a minimum area, giving the government legal and technical mining authority the power to extend or diminish such area according to the richness or poorness of the auriferous land, taking into account the required conditions and all circumstances, such, in fact, as we have previously indicated.

Probably ten years would be a sufficient period for the duration of an auriferous concession such as is now under discussion.

It is a grave error, productive of much prejudice, confusion, and injustice to the scientific world to argue and attempt to propagate as a doctrine of law—as the author of the present Argentine mining code has done—that “science is not capable of offering a classification of mineral



substances uniformly invariable, defined and acceptable, such as could serve for a legal basis." The writer has, however, always held a contrary opinion, for, it may be laid down as an axiom, that the practice and science of mining preceded, and, in fact, induced the law, as a necessity to define, protect, and regulate original rights and conflicting claims or differences which frequently arose when mining was in its infancy, and the common and equitable rights of the subject were not so well understood as at present, as also for the better exploitation and safety in working.

No doubt well founded arguments could be advanced against the practice of giving mining concessions, *ad libitum*, to persons who are not miners in the proper sense of the term, nor possessed of visible means to exploit a concession. If, finally, it should be decided to allow this custom to continue in force in South America, the law should, at least, compel every person applying for a mining concession to produce satisfactory evidence of their capabilities of carrying on a *bona-fide* exploitation.

The intention of the original legal dispositions contained in Article 2 of Title V., and of Article 1 of Title VII., of the *Ordenanzas de Minería*, was intended to assist the discovery, and advance the proper exploitation of the mines in South American Spanish colonies, from which the king of Spain could obtain benefit in the form of royalty upon the product of the mines. On the contrary, Article 18 of Title IX., determined all the rights conceded.

The same principles have been followed and incorporated in the present Argentine mining code, with the exception that the right of the state to receive a certain proportion of the profit derived from the mines has not yet been enforced.

It is a grave error in principle, and prejudicial to the mining interest, to group various classes of metalliferous mines in the same category, and to give to each the same area, as is the practice in the Argentine Republic, because each mineral substance differs the one from the other, whether gold, silver, copper, iron, or coal, including naturally every other economic mineral or crude rock, which may be employed and taken in commercial interchange: for, it is evident that each of these possess a certain relative, although different, market value.

The CHAIRMAN proposed a vote of thanks to Mr. H. D. Hoskold for his valuable paper, and it was cordially approved.

**THE NORTH OF ENGLAND INSTITUTE OF MINING AND
MECHANICAL ENGINEERS.**

SPECIAL GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
APRIL 10TH, 1897.

MR. GEO. MAY, PRESIDENT, IN THE CHAIR.

ALTERATION OF BYE-LAWS 13 AND 17.

The PRESIDENT moved that Bye-laws 13 and 17 be amended as follows :—

13.—The *Transactions* of the Institute shall not be forwarded to those whose subscriptions are in arrear on the first of November in each year.

17.—Any Member, Associate Member, Associate or Student may, at any time, compound for all future subscriptions by a payment in accordance with the following scale :—

Under 30 years of age, the sum of £31				
Over	30	„	„	27
„	40	„	„	24
„	50	„	„	21
„	60	„	„	17

or on such other conditions as the Council may, in writing, accept. Every person so compounding shall be a Member, Associate Member, Associate or Student for life, as the case may be. Any Associate Member, Associate or Student so compounding who may afterwards be qualified to become a Member, may do so, by election in the manner described in Bye-law 8. All compositions shall be deemed capital money of the Institute.

Mr. R. LAVERICK seconded the resolution, which was unanimously adopted.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND
MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
APRIL 10TH, 1897.

MR. GEO. MAY, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on March 29th and that day.

AWARDS FOR PAPERS.

The SECRETARY read the following list of papers communicated during the year 1895-96, for which prizes of books had been awarded by the Council to the authors :—

- "Coal-cutting by Machinery." By Mr. Wm. Blakemore.
 - "The Resistances of Air-currents in Mines." By Mr. T. L. Elwen.
 - "A Compound Winding-engine." By Mr. Wm. Galloway.
 - "The Quicksilver Mines and Reduction-works at Huitzuco, Guerrero, Mexico." By Mr. Edward Halse.
 - "The Whitehaven Sandstone Series." By Mr. J. D. Kendall.
 - "Notes on the Geological Features of the Coast of North Wales, from Liverpool to Menai Bridge." By Mr. C. E. de Rance.
 - "The Mode of Obtaining a True North Line." By Mr. A. L. Steavenson.
 - "Safety-explosives." By Bergassessor Winkhaus.
-

The following gentlemen were elected, having been previously nominated :—

MEMBERS—

- Mr. HENRY HOPPER ADAMS, Mining Engineer, Waihi, New Zealand.
- Mr. R. HUGH M. BUDDLE ATKINSON, Electrical Engineer, Fenwick Terrace, Newcastle-upon-Tyne.
- Mr. ROBERT BALLARD, Engineer, Menzies, Western Australia.

- Mr. MYLES BROWN, Manager, Shampore Coal Company, Nirshachetty P.O., Shampore, *via* Barakur, E.I.R., Bengal, India.
- Mr. ROBERT BROWN, Assistant Manager, Equitable Coal Company, Limited, Desherghur, *via* Barakur, E.I.R., Bengal, India.
- Mr. WILLIAM FRANCIS COLLINS, Mining Engineer, 220, Great Portland Street, London, W.
- Mr. WILLIAM DIXON, Mining Engineer, Cleator, Cumberland.
- Mr. WILLIAM FRYAR, Inspector of Mines, Brisbane, Queensland, Australia.
- Mr. THOMAS CARODOG KERRY, Explorer for Gold, Royal Colonial Institute, Northumberland Avenue, London, W.C.
- Mr. EDWARD THOMAS MORLAND-JOHNSON, Engineer and Surveyor, Bryn-Bowydd, Blaenau Festiniog, North Wales.
- Mr. ROKURO OSHIMA, Mining Engineer, Hokkaido Colliery and Railway Company, Sapporo, Japan.
- Mr. WILLIAM RIDLEY, Colliery Manager, Gilpin House, Houghton-le-Spring.
- Mr. JOHN WELSH, Mechanical and Mining Engineer, P.O. Box 1421, Johannesburg, South Africa.
- Mr. LUKE WILLIAMS, Mining Manager, Curtin-Davis Proprietary Mine, Ringville, West Coast, Tasmania.
- Mr. ROBERT ARNA WOOD, Mining Engineer, c/o Mr. N. R. Griffith, 18, Queen Victoria Street, London, E.C.

ASSOCIATE MEMBERS—

- Mr. THOMAS EDWARD HARDY, c/o Mr. M. Cohen, 20, Bucklersbury, London, E.C.
- Mr. E. JAMES, 24, Rosemont Road, Acton, London, W.
- Mr. THOMAS PASCOE, The True Blue Gold Mining Company, Kalgoorlie, Western Australia.

ASSOCIATES—

- Mr. R. AYNLEY, Surveyor, Littleburn Colliery.
- Mr. GEORGE BEWICK, Back Overman, Dudley Colliery, Northumberland.
- Mr. JOHN ROBSON ELLIOTT, Overman and Surveyor, Heddon Colliery, Wylam-upon-Tyne.
- Mr. CHARLES B. SANER, Surveyor and Assayer to the Gold-fields of Lydenburg, Mine Office, Rietfontein, Transvaal.
- Mr. JOHN SINCLAIR SMITH, Under-manager, Felling Colliery, Felling, R.S.O.

STUDENTS—

- Mr. NORMAN STANLEY HOLLIDAY, Mining Student, Langley Grove, Durham.
- Mr. CHARLES ATTWOOD HOOD, Mining Student, Hutton Henry Colliery.
- Mr. THOMAS TATE MINNS, Mining Student, Greenhill House, Murton Colliery, Sunderland.

Mr. JEREMIAH HEAD read the following paper on "The Coal-Industry of the South Eastern States of North America":—

THE COAL-INDUSTRY OF THE SOUTH-EASTERN STATES
OF NORTH AMERICA.

By JEREMIAH HEAD, M. Inst. C.E., F.C.S.

Fig. 1 (Plate VIII.) shows that portion of the United States of America which lies between the Atlantic Ocean and the Mississippi river; and contains also a small-scale key-map of the entire country. The line *AB* divides the Northern from the Southern States, the latter being those which took part in the great secession war of the years 1861 to 1865.

It is to the coal-industry of these states that the writer intends to devote this paper, and he proposes in the main to confine himself to those coal-fields and coal-workings with which he has some personal acquaintance.

The map (Fig. 1, Plate VIII.) shows approximately the principal coal-fields of the Southern States, which form part of the great Appalachian coal-field, extending 1,000 miles in a north-easterly and south-westerly direction from Canada to Alabama. This coal-field contains more beds of coal above water-level than any other coal-field in the United States. The map also shows the position of the chief deposits of iron-ore, which border on the coal-field and whose development is so often concurrent with that of the coal-supply.

Pocahontas District.—Beginning at the line dividing the Northern from the Southern States and working southward, the first coal-deposit is that of Pocahontas in Virginia. This deposit is one of the best known and most important of any in the Southern States. The coal is obtained from drifts in the hill side, and from one of these, the Baby Mine, 1,600 tons per day was being drawn at the time of his visit.

The principal coal-seam is from 5 to 13 feet thick, averaging about 9 feet thick. It is for the most part good solid coal. It is mixed here and there with a little shale, but nothing of a continuous character. There are two other coal-seams which have not yet been worked. The coal is all of coking quality, and a considerable quantity of it is made

into coke at a plant of beehive ovens in connexion with the colliery. The number of coke-ovens at work and under construction in the entire Pocahontas district had by the year 1891 reached a total of 2,785. These are all of the ordinary beehive type, 12 feet in diameter by 7 feet high inside. The usual charge is 4 tons of coal for 48 hours and $4\frac{1}{2}$ tons for 72 hours' burnings.

From the coke-ovens to the principal mine-entrance, and for at least $1\frac{1}{2}$ miles into the hill-side the main road is worked by full-gauge, full-size locomotives. The mine is operated on the pillar-and-stall system. The bye-roads to the working-stalls or rooms are at present very short. The ventilation is maintained by a rotary turbine-fan, which is very efficient. The quantity of air drawn from the mine is said to be 100,000 cubic feet per minute. The seam at present worked being above water-level, no pumping whatever is necessary; neither is any winding-plant required.

The lump coal is for the most part taken by the Norfolk and Western Railroad, on a branch of which the colliery is situated, to the port of Norfolk, in Virginia, whence it is shipped to New York and other markets. It is highly valued as bunker coal; and is accounted the best produced in the States for that purpose. It is largely used by the Atlantic liners in their eastward passages.

The coal royalties of the particular collieries described belong to the South-Western Virginia Improvement Company who receive a royalty of 10 cents or 5d. per ton* on the coal got. Their holding is said to be 8 miles long by 6 miles broad. The coal is sold by the mining company to a distributing company for 80 cents, or 3s. 4d. per ton into trucks; and the coke at \$1.75, or 7s. per ton. The railway rate to Norfolk, about 350 miles, is 0.4 cent. per ton per mile.

The miners are mostly Hungarians, who earn on piece work about \$4.25, or 17s. per day. The coal costs for the labour of getting 75 cents per car-load, containing 2 tons.

The following are analyses of Pocahontas coal and coke :—

					POCAHONTAS.*	
					Coal.	Coke.
Fixed carbon	...	...	...	...	74.256	92.549
Volatile hydrocarbons	...	...	...	...	18.812	0.756
Sulphur	...	...	...	...	0.73	0.598
Ash	...	...	...	...	5.191	5.749
Moisture	...	...	...	...	1.011	0.348

* *Journal of the Iron and Steel Institute*, 1890, vol. lli., pages 138-140.

* The United States ton for coal and coke contains 2,000 lbs.

The total output of coal from the Pocahontas coal-mines was, at the time of the writer's visit, said to be 800,000 tons per annum, and it appeared to be rapidly increasing. The yield of the principal seam so far as worked has proved to be 9,156 tons per acre, which corresponds with a realized thickness of about 8 feet of coal.

Big Stone Gap District.—In the State of Virginia, and about 80 miles south-west of Pocahontas, is the recently opened out coal-field of Big Stone Gap. The writer visited two mines in 1890, viz., the Pioneer, 1,850 feet above sea-level, and the Looney Creek at 1,900 feet. The Gap itself, which is a pass in the Cumberland Mountains, has an elevation of 1,450 feet. The Pioneer colliery is said to comprise at least 12 seams of coal, of which 8 or 9 are above 4 feet in thickness. In the heading which the writer entered, the coal measured 6 feet 1½ inches in thickness. The Looney Creek mine also contains several coal-seams, one of which was measured and found to be 14 feet thick. But as there were signs of lateral pressure at this place, it could hardly be taken to represent the general average thickness. These seams did not appear to contain any shale beyond a band about 3 inches thick near the middle.

The seams dip towards the north-west to the extent of 1 in 50, which is an advantage as regards working the traffic and drainage when the entries are made at the low side. The coal is a coking one, with the following analyses :—

					Coal.	Coke.
						Average of 7 Samples.
Fixed carbon	...	...	...	...	60.591	93.23
Volatile hydrocarbons	...	...	...	...	35.920	0.33
Sulphur	...	...	...	...	0.594	0.749
Ash	...	...	...	...	1.515	5.69

Recent letters from the States inform the writer that the Big Stone Gap coal-field is now being vigorously developed, and that the coke yielded by it is superior to that currently obtained from Connesville, in Pennsylvania.

The Middlesbrough District.—At Pineville, a little to the north of Middlesbrough, there are six workable coal-seams above water-level, and attached to the colliery is a large plant of coke-ovens.

The city of Middlesbrough, Kentucky (which is associated in the minds of British investors with the Middlesbrough Town Lands Company), is situated on the Kentucky portion of the Appalachian coal-field ; and its advantages of position, so loudly proclaimed, were largely based upon that circumstance. On Bennetts Fork, there are eight coal-seams,

visible at elevations varying from 600 to 1,200 feet. They range from 2 to 6 feet, with an aggregate thickness of 33 feet. So far, only one seam, the Ralston, has been worked. It yields nearly 5 feet of solid coal, with two partings of shale. The mode of working is to undercut in the 8 inches parting. The upper coal is then wedged down, and the under coal wedged up. The coal is suitable for coking.

The following analyses show the quality of both coal and coke produced at Middlesbrough and Pineville :—

MIDDLESBROUGH.				PINEVILLE.			
		Coal.		Coke.		Coke.	
		Average of		Average of		Average of	
		5 Analyses.		2 Analyses.		2 Analyses.	
Fixed carbon	...	58.64	...	91.20	...	95.27	
Volatile matter	...	37.67	...	1.17	...	0.22	
Sulphur	...	0.48	...	0.62	...	0.61	
Phosphorus	...	—	...	0.01	..	0.003	
Ash	...	2.16	...	6.29	...	3.54	
Moisture	...	1.05	...	0.71	...	0.36	

Jellico District.—One of the most important coal-mining districts in the Southern States is that lying partly in Tennessee and partly in Kentucky, west of the Knoxville and Ohio branch of the East Tennessee, Virginia, and Georgia railway. East of the same railway, the deposit is interfered with and cut off by the Pine Mountain range, which in places attains an altitude of 2,000 feet. The writer, who recently inspected and reported upon a group of five collieries, near the town of Jellico, called the Standard, Wooldridge, East Tennessee, Procter, and Main Jellico collieries (Fig. 2, Plate VIII.), found that the coal produced was a good house coal when in the lump, and a good steam coal when small. It is not a coking coal, and therefore is quite different in character from that produced at Pocahontas. The five collieries adjoin each other, and produce similar coal under similar conditions. They have separate branches connecting them with the Knoxville and Ohio railway, and are all held in fee simple both as regards surface and the minerals thereunder.

In each case, there is upon the property a village of wooden houses, and a boarding-house for the accommodation of single miners. A large provision and clothing store belonging to the mine owners is an important source of profit. A school, a chapel, residences for the officials and clerks, an office, mechanics' shops, mule stables, and storehouses, are also there; and, finally, there is a tipple-house which contains the screens and the weighing-machinery. The system of screening and weighing is simple, but very effective. The branch railway from below the tipple-house to the Knoxville and Ohio railway has a slight downward inclina-

tion, so as to make nearly equal work for the locomotive, whether taking full trains down or empties back. From the top of the tipple-house to the level of the Jellico coal-seam, which, with one exception—viz., the cancell seam,—is the only one worked at present, there extends a self-acting incline, or, in one case, a vertical lift.

Narrow-gauge railways connect the brow of the incline, or upper landing-stage of the lift, to the mine-entries, and are laid throughout the main roads of the mine. The traffic, inside and out, is worked by mules. There is no winding-machinery, nor any locomotives. The mine roads are all so laid out as to be always slightly in favour of the load. Each mine has usually three or four entries, all or any of which are utilized as circumstances may require.

The thickness of the Jellico coal-seam varies from 3 to 6 feet, the average being about 3 feet 9 inches. This is, as a rule, all good coal, there being no band or shale intermixed. The floor of the entries and roads is level with the bed of the coal-seam; the roof above is cut away in an ordinary mine-entry to give a height of about 6 feet, and the extreme width is about 8 feet. Timbering is done to a certain extent; but, the roof being exceptionally good, not very much is necessary. The seam dips towards the north-west, to the extent of 1 in 50. Full-gauge railways, with trestle-bridges, cost about £3,000 per mile; wooden houses for miners, from £24 to £32 each; mules, £30 each; and mine tubs, £6 each.

When the headings are properly laid out, they are self-draining; in some cases, however, this cannot be effected, and then a small engine at the mine-entry, pumping for half a day three times a week, is required to keep the water down. In other cases a syphon-pipe, 2 inches in diameter, is sufficient; but, as a rule, no pumping-machinery of any kind is provided.

There is nowhere any sign of dangerous gas. The ventilation is effected by air-shafts placed near the mine-entries; the tops of the shafts are not more than 30 or 40 feet above the mine-level. At the base of each, a coal fire is kept constantly burning; and the resulting draught is quite sufficient to ventilate the workings, so far as they have at present extended.

It will be at once apparent that these mines are exceedingly well situated for easy, cheap, and economical working; indeed, it is difficult to conceive more favourable conditions.

Fig. 3, Plate VIII., represents an imaginary section of a mountain in the Jellico district, containing seams of coal and other minerals. The

highest peak, called Ballads Point, is 2,250 feet above sea-level. All the seams illustrated are said to have been proved to extend throughout the district; but the writer only saw Nos. 4, 8, and 10 coal-seams. The very thin seams are of no commercial value. The seams below water-level would require winding and pumping appliances, and are therefore not likely to be brought into requisition until the most important of the upper ones have been exhausted.

The total acreage of coal remaining in the Jellico coal-seam at the five collieries is estimated at 12,000 acres, and this acreage, reckoned at 100 tons per inch thick per acre, would yield 52,800,000 tons. If we take the other workable seams as equivalent to the same area by 6 feet thick, we should obtain a further quantity of 86,400,000 tons, or an aggregate of 139,200,000 tons; which, consumed at the rate of 1,000,000 tons per annum, would be sufficient to last 139 years.

The cannel seam is found in only two of the five coal properties described, and is worked only at one, viz., the Standard colliery. The seam varies from 28 to 42 inches thick. Only about 150 tons per day are obtained, and this is mostly sent to New York as an ingredient for improving coal-gas. The cost price delivered in cars at the junction with the Knoxville and Ohio railway was, at the time of the writer's visit, about \$1.85 (7s. 6d.), and the price then obtainable about \$3 (12s.) per ton. It is probable that the development of the Humphrey and Glasgow process for producing and enriching illuminating-gas, which is now so largely used in America, and in which coke and petroleum are the materials used, may have by this time seriously diminished the value of and limited the demand for cannel coal for such purposes.

The lump or block coal, which passes over screen-bars 7 inches apart, is sold as house coal, and is highly estimated as such. It burns very freely, leaves a light grey ash, and gives out an abundance of heat. It constitutes about 50 per cent. of the whole produce. The remaining 50 per cent. is further sorted into No. 2 screened, nuts, and slack, and these quantities are variously mixed according to demand.

The total produce of these five collieries was at the time of the writer's visit, comparatively small, viz., rather under 300 tons per colliery per day. The average selling price per ton, free on cars at the Knoxville and Ohio junction, was as follows:—

	Per Ton of 2,000 lbs. Dollars.	Per Ton of 2,240 lbs. s. d.
Average of all grades	1.30 ...	6 1
„ with slack excluded	1.34 ...	6 3
Lump coal	1.73 ...	8 1
Run of mine and No. 2 screened ...	1.18 ...	5 6
Nuts	0.86 ...	3 10
Nuts and slack	0.60 ...	2 10
Slack	0.22 ...	1 0
The average profit, exclusive of that realized from the stores, was, per ton of coal	0.21 ...	0 11½

The following analyses from samples of coal from the five Jellico collieries were made by Messrs. Pattison & Stead, analysts, Middlesbrough:—

	Coal. Per Cent.	Coke. Per Cent.	Cannel Coal. Per Cent.
Fixed carbon	55.76 ...	91.79 ...	37.05
Volatile hydrocarbons	36.51 ...	0.00 ...	44.70
Sulphur	1.08 ...	0.89 ...	0.78
Ash	4.45 ...	7.32 ...	15.85
Moisture	2.20 ...	0.00 ...	1.62
Sulphur in ash	0.01 ...	— ...	0.02
Yield of coke	60.75 ...	— ...	—

The cannel coal gives out a large quantity of gas of a highly illuminating quality.

Coal Creek District.—About 30 miles south of the Jellico group of mines, and on the same side of the Knoxville and Ohio railway, the Coal Creek Mining and Manufacturing Company own about 60,000 acres of coal-lands. This company leases mineral rights for a royalty of 25 cents per ton, to the following lessees who actually win the coal, viz., the Knoxville Iron Company, who work 3 mines; the Black Diamond Company, 3 mines; the Coal Creek Company, 2 mines; the Tennessee Coal Mining Company, 1 mine; and the Heek Mining Company, 1 mine; a total of 10 mines.

About half of the output of these mines was sold at the time of the writer's visit to the railway company as "run-of-mines" coal (or unscreened) at \$1.15 per ton, or say 5s. 5d. per 2,240 lbs. Of the remainder, a portion was sold for gas-making. The coal is somewhat friable, not more than 30 to 40 per cent. being obtained as lump.

Between the Coal Creek and Jellico collieries, the East Tennessee Iron Company own 150,000 acres of land, a considerable portion of which is coal-bearing. At the time of the writer's visit it was worked only by one lessee, viz., the Pioneer Coal Company, whose headquarters

are at Buckeye, 48 miles from Knoxville. The output of the Coal Creek collieries was then about double that of the Jellico group. The Pioneer mine was turning out a little under 100 tons per day. It is claimed that this company's coal is of a good coking quality.

Poplar Creek District.—Near Poplar Creek, 80 miles from Knoxville, there are deposits of coal similar to those belonging to the Coal Creek Company. These were worked by the Richards Brothers Company and the Cumberland Coal Company, whose united production was about 400 tons per day, and also some other operators on a small scale. This coal was the earliest worked in the upper part of Eastern Tennessee. A small blast-furnace at Oakdale, 25 miles distant, making from 40 to 50 tons of pig iron per day, was long supplied with coke made from it.

Emory District.—Sixty miles west of Knoxville is the Emory mine, belonging to the Harriman Company. The seam is 4 feet thick and produces a coking coal. The coke has been used to a considerable extent at the Cowan and South Pittsburgh blast-furnaces. The coal has the following analysis:—

						Per Cent.
Fixed carbon	...	...	...	...	...	63.10
Volatile matter	...	...	...	...	...	27.70
Ash	...	...	...	...	...	7.70
Sulphur	...	...	...	...	...	0.50

The writer understands that arrangements are now being made to combine in one large company, all, or nearly all, of the collieries at present served by the Knoxville and Ohio railway. The combination will include the Jellico, Coal Creek, and Poplar Creek districts, and possibly some others. It is intended when the syndicate secures control to operate everything requiring power by electricity, except the branch railways, where steam locomotives will be retained. Coal-cutting machines will be used of the Thompson-Houston type.

Chatanooga District.—South-west of Knoxville, is the important city of Chatanooga, Tennessee, and a little to the west of this the Appalachian coal-field is worked at various points which may be conveniently considered in four districts, called Cumberland Mountain, Walden Ridge, Sand Mountain, and Look-out Mountain.

All the mines at present operated in these districts are above water-level. The mountain-tops have in places an elevation of 2,000 feet. The mine-entries are in the hillsides, and the seams and roads are nearly

level, as at Jellico. The Sewanee is the most important seam at present worked, and yields about $3\frac{1}{2}$ feet of coking coal, of the following average composition :—

	Coal.	Coke (from unwashed coal).
Fixed carbon	60·0	84·188
Volatile matter	30·0	0·569
Ash	9·3	14·141
Sulphur	0·7	0·182

It is largely worked at Tracy City. The next seam in importance is the Main Etna, or Cliff vein, which varies from $1\frac{1}{2}$ to 7 feet thick, averaging about 3 feet. It makes a fairly good coke.

Birmingham District.—We now come to the important coal-fields in the State of Alabama, of which the city of Birmingham is the focus, and to which, to a great extent it owes its existence; as also does the neighbouring city of Bessemer, and several others. The principal Alabama coal-fields are :—

	Square Miles.
Warrior, estimated to extend over	7,800
Cahaba ,, ,,	400
Coosa ,, ,,	345
Total	8,545

These coal-fields differ essentially from those already described, in that they do not exist as a succession of flat beds in mountains at a considerable elevation above the sea; but as a series of parallel elliptical synclinal basins below the ground-level, with their outcrops rising to it all around. The Forest of Dean coal-field is of the same nature, and in South Wales there are coal-deposits of both kinds. The general strike of these coal-basins is from north-east to south-west. The dip is naturally greatest at the outcrop, then gradually lessens, and disappears; and finally rises in the same way on the opposite side.

The Warrior coal-field contains no less than fifty seams, of which twenty-five are thought to be workable, but only three are actually worked. The thickness of the coal in these varies from 3 to 14 feet.

The Cahaba deposit contains twenty coal-seams, of which three, from 2 to 6 feet in thickness, are worked.

The total production of the Alabama coal-field was :—

In 1870	...	...	...	11,000 tons.
„ 1880	...	...	...	340,000 „
„ 1886	...	...	...	1,800,000 „
„ 1889	...	...	...	2,903,350 „

Since 1890, the coal and iron trades have been suffering from a terrible depression, from which they are only just recovering, and therefore recent statistics do not indicate the productive powers of the district.

The Alabama coal is mostly of a coking quality. In 1890, there were 4,647 coke-ovens built, and 270 under construction; but, by the end of 1891, the number had increased to 6,000. With the exception of 64 Thomas coke-ovens, all the ovens are of the ordinary beehive type—10½ to 12 feet in diameter, and 5 to 7 feet high inside. The charge is usually 5 tons of small coal, which produces 3 tons of coke.

In the principal, or Great Warrior, coal-field there are numerous mines, for the most part with coke-burning plants attached. The following are typical ones—viz., Blue Creek, Pratt, Adger, Blockton, and Johns mines.

A section of the main coal-seam worked at the Blue Creek mine is as follows :—

Roof-stone.				Ft.	Ins.	Ft.	Ins.
Coal	...	...	...	0	8		
Band-stone	...	...	...	0	2		
Coal	...	...	...	5	0		
Band-stone	...	...	...	0	1		
Coal	...	...	...	1	0		
Band-stone	...	...	...	0	0½		
Coal	...	...	...	1	6		
						8	5½
Thill-stone.							

Average analyses of the coal of the Warrior coal-field, and of the coke made from washed and unwashed coal, are given below :—

				Coke.	
Coal.				From unwashed Coal.	From washed Coal.
Fixed carbon	...	...	61·51	87·02	90·48
Volatile matter	...	...	31·48	1·02	1·11
Ash	...	...	5·42	10·12	7·50
Sulphur	...	...	0·92	1·77	0·83
Moisture	...	...	0·67	0·07	0·08

With one exception, these mines are all worked from the outcrop, the winding-shafts being at such an angle with the horizon as will admit of entrance and egress on foot. The tubs are hauled in and out by engines and wire ropes running on rollers. There are three entries at the Blue Creek mine, which are together capable of yielding 2,500 tons of coal per day.

The one exception referred to is one of the Pratt mines, which has a shaft 200 feet deep, worked by a winding-engine and head-gear in the

usual way. Pumping is effected by a force-pump below, driven by air compressed at the surface. This mine alone produced over a million tons of coal in 1889.

Under the system of working prevalent in the Alabama districts, galleries are driven off the main slope at intervals of 300 feet. The intervening body of coal is worked out by driving stalls 40 feet wide, and 60 feet from centre to centre, for a distance of about 275 feet. This leaves a pillar of 20 feet between the stalls, which is worked back to the heading, as soon as the stalls are finished. In this way all the coal is taken out between the galleries, leaving pillars to protect the entries. When the galleries have been driven about 3,000 feet even these pillars

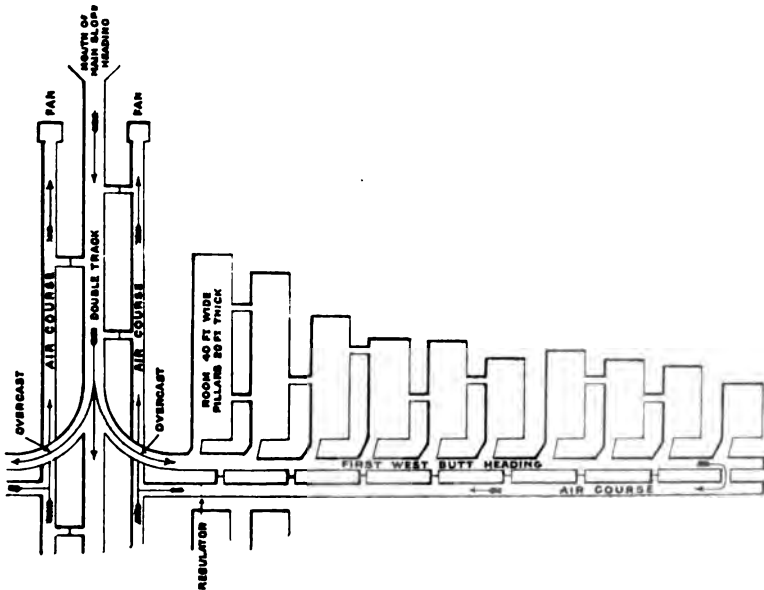


FIG. 4.—SKETCH-PLAN SHOWING METHOD OF WORKING AND VENTILATION OF NOS. 4 AND 5 SLOPES, PRATT MINES, ALABAMA, U.S.A. Scale, 300 Feet to 1 inch.

are removed. By this means not more than 5 per cent. of the available coal is lost. Ventilation is usually effected with one continuous current, but sometimes a split-current is adopted. In that case, a Guibal fan is placed at the air-shaft, on each side of the main haulage-slope, so that each side is independent of the other, and each gallery takes its supply of fresh air direct from the main slope (Fig. 4). The hewing is generally done by hand; but at the time of the writer's visit 13 Harrison pick-machines were in use: they are able to undercut to a depth of $4\frac{1}{2}$ feet, along 90 feet of face, with one attendant per shift.

At the time of the writer's first visit to Alabama, in 1890, the coal-slack was nowhere submitted to a washing-process before being charged into the coke-ovens. The disadvantages arising from the comparatively poor calorific value of the resulting coke was felt to be a serious drawback to the development of the iron trade. Consequently great attention was given to coal-washing plant, and it was not long before the Robinson and Ramsay coal-washers were introduced and adapted to American requirements. The writer believed that all coke now used at Alabama blast-furnaces was produced from washed coal-slack. The beneficial results were shown in the comparative analyses which he had given, and had contributed materially to make possible the extraordinary development which was at present in progress in the Southern pig iron trade. At the Pratt mines coking-plant, flues, built in the walls between the ovens, and communicating with them, draw off a portion of the gases and convey them to the boilers, where they are burnt. It was claimed that no less than 375 tons of coal per week was saved by this arrangement.

If we take the area of the three principal Alabama coal-fields, at the estimate already given, viz., 8,545 square miles, which is equivalent to 5,468,800 acres, and reckon the workable coal at 8 feet 4 inches thick in the aggregate; and as yielding 100 tons per inch per acre, we shall find that the total quantity of coal is 54,688,000,000 tons, which consumed at the rate of the present total production of Great Britain (viz., 180 million tons per annum) fixed the duration of the Alabama coal-field at 308 years.

At the time of the writer's last visit to Alabama, viz., in the autumn of 1894, the price of coke delivered at the blast-furnaces was about 6s. 9d. per 2,240 lbs., or half the current price in England.

Negro labour is mainly employed. The latitude being about the same as that of Morocco, and the climate being, therefore, almost tropical, the population requires less food and protection than in colder regions. Great efforts were made in the spring of 1894 by the leaders of the local trades unions to force the negroes into their organization. When they found that impossible, they endeavoured to frighten them out of the trade. Several were shot, others maltreated, and for a time mine-managers went about armed with revolvers. By aid, however, of a loyal militia, headed by a capable and courageous governor, the trade unionists were eventually beaten; and thenceforth the South, having the benefit of cheap negro labour, has been able to compete advantageously in all parts of the United States.

The distance from Birmingham to the Gulf ports is 258 miles to Pensacola, and 276 miles to Mobile. The railway rate to the former port, including shipping charges, is 4s. 6d. per ton, or say 0·20d. per ton per mile. This rate enables coal-producers to put coal free-on-board at these ports for, say, 8s. per ton, or as low as bunker coal at the north-eastern ports of Great Britain. The railway facilities enjoyed by the Americans are in striking contrast with their absence here, British heavy products having to pay from three to five times the above rates per ton per mile.

It is not, however, in direct coal-exportation that British producers need fear American competition. It is more in heavy goods, such as pig-iron, steel rails, and billets, which absorb in their manufacture from $1\frac{1}{2}$ to $2\frac{1}{2}$ times their own weight in fuel. In the case of such exports, only one railway and sea freight is paid on all material used in producing 1 ton of product carried. Such goods are also practically undamageable, and are not much affected by delays of transit; and being useful as ballast they are taken at low sea-freights along with cotton cargoes. Alabama pig-iron so favoured, is already arriving in considerable quantities in European markets; and so for the time being at all events, coals, or the products into the manufacture of which they enter are being literally "carried to Newcastle," or right into several of the coal-producing districts of Europe.

In conclusion, the writer desires to acknowledge his indebtedness to the several colliery proprietors, engineers, and others in America, who have given him much of the information comprised in his paper; and also to his son and partner, Mr. A. P. Head, who accompanied him on his journeys, made the illustrations, and assisted him throughout.

An Appendix is added, which recapitulates, in a single table, the typical analyses of the coals and cokes produced in the South-Eastern States of the United States of America.

APPENDIX.

I.—ANALYSES OF COAL.

	Fixed Carbon.	Volatile Matter.	Sulphur.	Ash.	Moisture.
Pocahontas, Virginia ...	74·256	18·812	0·73	5·191	1·011
Big Stone Gap, Virginia ...	60·591	35·920	0·594	1·515	—
Middlesbrough, Kentucky ...	58·64	37·67	0·48	2·16	1·05
Jellico, Kentucky ...	55·78	36·51	1·08	4·45	2·20
" " cannel coal	37·05	44·70	0·78	15·85	1·62
Emory, Tennessee ...	63·10	27·70	0·50	7·70	—
Sewanee, " ...	60·00	30·00	0·70	9·30	—
Warrior coal-field, Alabama ...	61·51	31·48	0·92	5·42	0·67

II—ANALYSES OF COKE.

	Fixed Carbon.	Volatile Matter.	Sulphur.	Ash.	Moisture.	Phos- phorus.
Pocahontas, Virginia ...	92.549	0.756	0.598	5.749	0.348	—
Big Stone Gap, Virginia ...	93.23	0.33	0.749	5.69	—	—
Middlesbrough, Kentucky ...	91.20	1.17	0.62	6.29	0.71	0.01
Pineville, Kentucky ...	95.27	0.22	0.61	3.54	0.36	0.003
Jellico, Kentucky ...	91.79	—	0.89	7.32	—	—
Sewanee, Tennessee ...	84.188	0.569	0.182	14.141	—	—
Warrior coal-field, Alabama, from unwashed coal ...	87.02	1.02	1.77	10.12	0.07	—
Warrior coal-field, Alabama, from washed coal ...	90.48	1.11	0.83	7.50	0.08	—

The PRESIDENT remarked that the coal-fields described in Mr. Head's paper were very extensive. The colliery owners were evidently interesting themselves in improving their position by the use of electric machinery.

Mr. A. L. STEAVENSON said that it was especially desirable that all the coal-fields of the world should be described in the *Transactions*. Mr. Head's paper gave a description of the important coal-fields of the South Eastern States of America, and it might perhaps induce some of the members to go there and become not only managers, but owners of mines. A little while ago he was discussing in the electrical papers as to how it was that such a small amount of machinery was used in British mines. He said that it was because they were not worked on the longwall system, and therefore coal-cutting machinery was not applicable. One of the American papers replied that longwall was not generally worked, and he (Mr. Stevenson) wanted to ascertain how, if they worked on the pillar-and-stall system, they were able to use coal-cutting machinery. The *Engineering Magazine** contained a paper on "The Growing Efficiency of Modern Machinery," and it described what was being done with electrical coal-cutting machines, as follows:—

The mining rates agreed upon some time ago between the coal-operators and miners were as follows:—For pick-mining, hand, 75 cents per ton, for which sum the miner undercuts the coal, drills and shoots it, and loads it into the mine-car at the face, ready for the driver to take away to the tippie; where machines are used, 38 cents per ton is paid for drilling, shooting, and loading, 15 cents per ton for undermining the coal with the pick type of machine, and 9½ cents when the under-cutting is done with the breast machine. Therefore we have a cost of 53 cents per ton for loaded pick-machine coal, or an apparent saving of 22 cents per ton, while,

* 1897, vol. xiii., page 89.

To illustrate Mr. Jeremiah Head's Paper on "The Coal-Industry of the South-Eastern States of North America."

Fig. 1

SECTION THROUGH COALFIELD

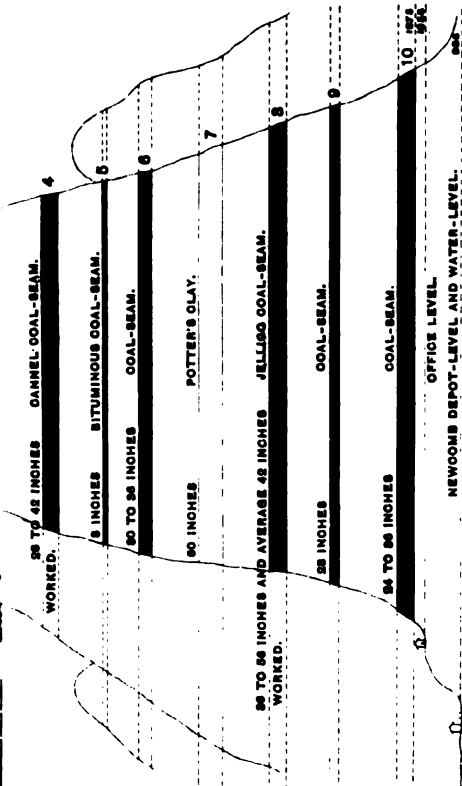
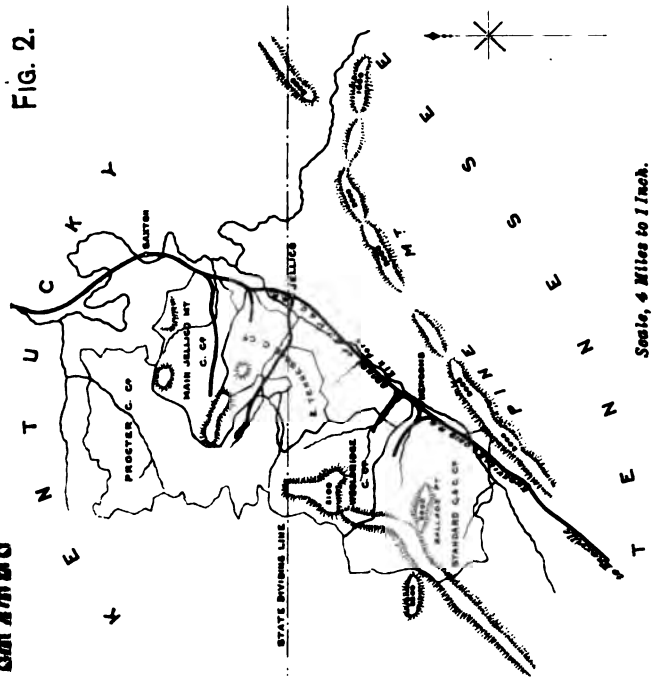


Fig. 2.



with the breast type of machine, the apparent saving is 27½ cents per ton. If this saving could be realized by substituting machinery for hand labour, we should expect to witness the closing of mines that cannot afford to put in machinery; but, as 50 per cent. of the apparent saving is practically consumed in operating expenses, and as 35 per cent. of the balance must be credited to interest and depreciation, the net saving is reduced to nearly 10 cents per ton, which in itself makes a good return on the investment.

A cost of 75 cents was about equal to 8s. 1½d., and the rate for bituminous coal Mr. Head spoke of was double the price it costs in Britain. Even if they saved 10 cents or 5d. a ton they were still about 1s. per ton above British prices.

It would be seen from the analyses of the coals and coke that, with the exception of the Pocahontas coal, they contained about 60 per cent. of fixed carbon, and were not quite equal to best Durham coking coal. The volatile matter in the coke was less than 1 per cent., and he (Mr. Steavenson) attributed this to the fact that it was nearly all burnt in beehive coke-ovens. The owners of bye-product ovens were anxious to have all the bye-products they could get, and as soon as gas was seen upon the coke they stopped the oven and doused it with water; but in his case, he soon received a complaint if the coke contained an excess of volatile matter or water.

Mr. G. B. FORSTER asked whether, in the Pocahontas district, the hewing or cutting was done entirely by machinery. In looking over the costs and statistics one was struck with the high wage that the men received as compared with the low tonnage cost; perhaps that could be explained by the larger use of machinery. Referring to Mr. Steavenson's remarks he might observe that there was latterly a large proportion of coal worked in Northumberland on the longwall system, and probably coal-cutting machinery would come into vogue. So far as their present experience with coal-cutting went, however, he thought that while they might get a better article they would not get a lower cost.

The PRESIDENT said that the Harrison mining-machine was tried at Ryhope colliery in ordinary bords and walls similar to those described in Mr. Blakemore's paper.*

Mr. J. R. GILCHRIST remarked that the Ingersoll machine was used in this country.

Mr. J. HEAD, replying to Mr. Steavenson's questions, said that he had not actually seen coal-cutting machines at work, although he believed that

* *Trans. Fed. Inst.*, vol. xi., page 179.

he had mentioned in the paper those collieries where they were in use. He believed, as had been stated, that the Harrison coal-cutting machine was capable of being applied to the pillar-and-stall system. The Thompson-Houston was a chain cutter-machine, and more especially suitable for longwall working. The wages paid at Pocahontas, of course, varied very much. In 1890, trade was in a very inflated condition in America, as it was at home, and corrections should always be made for the date.

Mr. G. B. FORSTER supposed that the prices of coal given in the paper were for the same dates as the wages mentioned.

Mr. HEAD said that the prices and wages were given for the same dates.

Mr. G. B. FORSTER asked whether Mr. Head could give the number of tons equivalent to a day's work, and whether machines were used.

Mr. HEAD said he was not aware that machines were employed at the Pocahontas mines in 1890.

The PRESIDENT proposed a vote of thanks to Mr. Head for his interesting paper.

Mr. G. B. FORSTER seconded the resolution, which was passed with acclamation.

Mr. JEREMIAH HEAD briefly acknowledged the compliment.

The following "Notes on the Sinking of Two Shafts at Claravale Colliery, near Wylam-upon-Tyne," by Mr. Frank R. Simpson, was taken as read :—

NOTES ON THE SINKING OF TWO SHAFTS AT CLARAVALE COLLIERY, NEAR WYLAM-UPON-TYNE.

By FRANK R. SIMPSON.

The writer, in giving a short account of the sinking of the shafts at Claravale colliery, intends principally to describe the difficulties encountered from large feeders of water, and generally the arrangement of machinery adopted in the accomplishment of the work.

The Claravale colliery is one of a group of five collieries owned by the Stella Coal Company - viz., Emma, Addison, Stargate, Blaydon Main, and Claravale—which, combined, have a yearly output of about 600,000 tons of coal.

Claravale colliery is situated 1 mile east of Wylam station, and stands on the south side of the Carlisle branch of the North-Eastern Railway. There are two shafts, 99 feet apart, each 14 feet in diameter, and both have been sunk to the brockwell seam, which lies at a depth of 395 feet. The sinking of these shafts, owing to the extraordinary quantity of water, occupied a period of over three years. When it was first determined to sink these shafts, every endeavour was made to ascertain what feeders of water were likely to be met with, and the result of these enquiries showed that a quantity of 500 gallons per minute was the probable maximum. It was therefore determined to sink the pits with the pumping-arrangements applied to the winding-engine, and to erect a large Hathorn-Davey pumping-engine (as a permanent plant) to raise 2,500 gallons per minute, and thus to carry out an extensive scheme of drainage for three of the collieries. Instead, however, of a feeder of 500 gallons, there was found the quantity of 2,000 gallons per minute for some time, and of 1,100 gallons per minute permanently. If, of course, by any possible means, the actual feeder could have been foreseen there would have been very much less difficulty and delay attached to the winning, as machinery of sufficient power would have been made ready and applied in the beginning.

It being decided that the shafts should be 99 feet apart, a temporary heapstead was erected, with a sinking-engine for each shaft, as shown in Figs. 1, 2, and 3 (Plate IX.). Sinking operations were commenced at

the No. 1 shaft on April 22nd, 1890. The sinking-engine at this shaft had two horizontal cylinders, each 14 inches in diameter by $16\frac{1}{2}$ inches stroke, drum 5 feet in diameter, and geared at 4 to 1.

The No. 1 shaft was marked out with a diameter of $16\frac{1}{2}$ feet, but the sandy nature of the ground soon obliged this to be increased to $19\frac{1}{4}$ feet. On the following day a small quantity of water appeared in the shaft, and caused the sides to fall in. The sand was cast out, and four oaken cribs, 6 inches square, with battens 7 inches by $2\frac{1}{4}$ inches, were inserted. The water, becoming troublesome, was taken out at intervals by a water-tub, which emptied into a cistern fixed on the heapstead.

The next operation was the driving of piles from the surface 7 inches by $2\frac{1}{2}$ inches by 15 feet long, shod with iron, the shaft being thereby reduced to $17\frac{1}{2}$ feet in diameter. The water at this stage was $18\frac{1}{2}$ gallons, and as it gradually increased to 26 gallons per minute, sinking ceased, until a special pump, 6 inches in diameter by 2 feet stroke, and steam cylinder 12 inches in diameter, was fixed on a baulk 12 inches square, and hung in the shaft by a rope from the crab-engine.

The stone-head was reached at a depth of 31 feet, and sinking continued, with short interruptions for lowering the special pump, till a depth of 87 feet was reached. At this point a feeder of water was tapped, and, increasing from 20 to 200 gallons per minute, the special pump could not cope satisfactorily with it.

Sinking was, therefore, discontinued till a lifting-sett, 18 inches in diameter by 6 feet stroke, was attached to the winding-engine (Figs. 1 and 2, Plate IX.). The horizontal winding-engine with two cylinders, each 24 inches in diameter and 5 feet stroke, actuated the pumps by means of a crank applicable for 5 or 6 feet stroke on the second motion-shaft, on which was a spur-wheel $12\frac{1}{4}$ feet in diameter, driven by a pinion $5\frac{7}{8}$ feet in diameter on the drum-shaft. The pumping quadrant was connected to the crank by a connecting-rod in two pieces (Fig. 2, Plate IX.). The pumps were hung in the shaft by hanging-spears of pitchpine 8 inches by 6 inches, in lengths of 30 feet, attached to the ground-crab by a hemp rope, 8 inches in diameter, passing over the pulley-blocks, as shown in Figs. 4, 5, 6, and 7 (Plate X.).

While this machinery was being erected, a concrete ring 3 feet deep by 2 feet wide was formed in the shaft, and walling proceeded with, the finished diameter of the pit being 14 feet. The walling consists of fire-clay lumps, 9 inches wide by 6 inches deep by 12 inches long, moulded to suit the circumference of the shaft.

On the erection of the pumping-arrangements (Fig. 8, Plate X.), sinking was resumed; but the feeders increased very rapidly, till they reached 450 gallons, and later 600 gallons, per minute. Unfortunately, at this time the bed-plate of the winding-engine was broken, and delayed the work for two or three days; but, after this damage had been repaired, all went well, the feeder remaining at 600 gallons, until the towneley seam was reached at a depth of 191 feet $2\frac{1}{2}$ inches. It may here be remarked that No. 2 pit was being sunk during the time occupied in the above operations (Fig. 9, Plate X.). Having reached the towneley seam, a scaffold was fitted up, and a heading was driven 99 feet, and holed into the bore-holes, which had been put down in advance of the sinking in No. 2 pit. While this connexion was being made, a length of walling was completed.

On resuming sinking, the next difficulty encountered was a feeder of 200 gallons, bringing the total up to 800 gallons per minute; and it was deemed necessary to fix a special pump, with a steam-cylinder 21 inches in diameter, and a pump-barrel $14\frac{1}{4}$ inches in diameter and 3 feet stroke, in the towneley seam to raise to the surface the water which was collected from both shafts above that seam. Considerable trouble was caused by the bursting of the working-barrel of this special pump, which twice occurred, and in each case immediately on starting—in fact, no water was pumped—and it was decided to substitute a different type of pump. The type of special pump which failed in two instances, immediately on starting to pump, was that in which the working-barrel and clack-seats were formed of one casting, and that which proved successful was that in which the clack-seats were made of separate pieces, known as the box-type, as in the case of the Hathorn-Davey underground pumping-engine.

During the time when this special pump was being fixed, headings were driven east and west in the towneley seam.

Shortly after the new special pump was set to work, and sinking resumed, the pumping-crank of the winding-engine sett failed, by a fracture near to the pin-hole. No serious delay ensued, as the crank had been provided with a second pin-hole, so as to enable the pumps to be worked with a 5 as well as a 6 feet stroke.

When the sinking arrived at the white sandstone overlying the tilley seam, a large feeder of 500 gallons (making a total of 1,800 gallons per minute) was met with, and quickly increased to 2,000 gallons, to be raised to a height of 230 feet. The winding-engine pumping sett, on which a new 6 feet stroke crank-pin had been fitted, was kept going at fifteen

strokes per minute, and water-tubs were worked by the sinking-engines in each pit, but the water could not be lowered. Eventually, after struggling for some time with this feeder of 2,000 gallons per minute, sinking was abandoned until the permanent pumping-engine was erected. This engine was a Hathorn-Davey compound expansive condensing engine, fitted with steam-jackets; the low-pressure cylinder was 68 inches and the high-pressure cylinder 38 inches in diameter by 10 feet stroke, working at a boiler-pressure of 80 lbs. per square inch. The engine worked a single lifting-sett, with a bucket 24 inches in diameter, at the No. 2 shaft. This lifting-sett arrangement was only temporarily used for sinking purposes, and was afterwards replaced by two ram-pumps 22 inches in diameter, as will hereafter be described.

After a delay of about three months, the 24 inches sett of pumps was ready for work, and sinking was resumed with one sett of pumps 18 inches in diameter in No. 1 pit, and one sett 24 inches in diameter in No. 2 pit; but as the feeder still varied from 1,700 to 2,000 gallons per minute, it was determined to tub off the sandstone lying above the tilley seam, which was extremely porous, and notorious in this district for its feeders of water (Fig. 10, Plate X.). With this purpose in view, a bed was formed for a wedging-crib in a stratum of blue metal, which was impervious to water, and situated 6 feet below the post or sandstone. A length of 36 feet of tubing, in segments 4 feet long by 2 feet high by $\frac{3}{4}$ inch thick, was accordingly placed in both shafts. When all was sealed off, it was found that about 950 gallons per minute had been kept back by the tubing. Up to that time, the 18 inches sett of pumps, down to a depth of 271 feet, had been delivering to the surface; but the delivery was now turned into the towneley seam, and so flowed along the drift between the shafts to the 24 inches sett of pumps in No. 2 pit (Fig. 11, Plate X.).

When the sinking had attained a depth of 356 feet, the feeders were 1,030, and at 364 feet 1,100 gallons per minute, which quantity was maintained until the brockwell seam was reached at a depth of 393 feet; and, in fact, it is the constant feeder of the colliery at the present time, after three years of working.

So far, the sinking of No. 1 pit has been briefly described, and it is now desirable to consider the progress made by the No. 2 pit. There was no particular difficulty in the sinking of this shaft, as the water drained from it to No. 1 pit until a depth of 68 feet was reached (Figs. 8 and 9, Plate X.), when it was found necessary to put down a bore-hole 3 inches in diameter to the towneley seam, in which a connexion had

been made from the No. 1 shaft. Before reaching the towneley seam, the 3 inches hole was found to be too small, and it was enlarged to 4 inches in diameter; but even then it was incapable of running off the water to No. 1 pit, and finally a second hole, 7 inches in diameter, was bored, which enabled the towneley seam to be reached. It was at this stage that the special pump before mentioned was erected, and the accompanying difficulties of the failure of the working-barrels ensued. When the improved type of special pump had been erected, sinking progressed favourably until the sandstone overlying the tilley seam was encountered.

As in No. 1 shaft, all operations were abandoned until the main pumping-engine, temporarily adapted to work a lifting-sett 24 inches in diameter and 10 feet stroke, was ready. When this pumping-plant had been erected, sinking was resumed, the 24 inches sett of pumps being hung by hanging-spears of pitchpine 10 inches by 8 inches, in lengths of 40 feet, and attached to a special steel galvanized rope 3 inches in circumference, passing over 4 and 3 pulley-blocks, as shown in Figs. 4, 5, 6, and 7 (Plate X.). An accident then occurred, which illustrates the extreme care necessary in dealing with heavy pumping appliances. While a short pump was being added, the Y-bolts, which connect the spears to the quadrant, being loosed, the spears slipped away and broke the crab-chain (made of $1\frac{1}{4}$ inch B.B.B. iron having a breaking strain of 45 tons) and also so damaged the crab-rope socket that it had to be replaced.

As soon as the sandstone above the tilley seam was drilled into, more water appeared and quickly rose in the bottom of the shaft, and as illustrating the open nature of this rock, it was found that the water had come from No. 1 pit, leaving it quite dry. The feeders at this time were 2,000 gallons per minute, as described in the sinking of No. 1 shaft. The tubbing-off of the tilley seam sandstone was then completed.

Sinking with the 24 inches sett of pumps had now reached a depth of 245 feet, and the weight became so great, viz., 100 tons hanging over blocks on a steel-rope 3 inches in circumference, that it was not thought advisable to carry it to any greater depth. To obviate this difficulty, a cistern was fixed just below the towneley seam, and the 24 inches sett of pumps was lifted to this point (Fig. 11, Plate X.). The arrangement of delivery was now as follows:—Bore-holes having been put down to the three-quarter seam, and a connexion made in that seam from the No. 1 shaft, the water was conveyed thereby to the 18 inches sett of pumps, which delivered into a cistern, from which the 24 inches sett of pumps delivered to the surface (Fig. 11, Plate X.). After con-

tinuing the sinking favourably for some time, a serious accident occurred: a spear-joint of the 24 inches sett of pumps gave way, all the bolts $1\frac{3}{8}$ inches in diameter having failed, causing the pistons to move so rapidly that the cover of the low-pressure cylinder (68 inches in diameter) was split in several places. The damage was temporarily repaired by plating, and eventually a new cover was obtained.

It may be mentioned that, owing to the enormous quantity of water and to the rapidity with which it rose in the pit-bottom, it was quite impossible to change either the clacks or the buckets at the doors, and consequently, whenever a failure occurred, which was very frequent, the slow and laborious task of lifting the whole of the spears to the surface and fishing for the clack had to be resorted to.

When a depth of 327 feet had been reached, the placing of the permanent ram-pumps was commenced. There are two ram-pumps each 22 inches in diameter by 10 feet stroke, and the rising main-pipe 20 inches in diameter is common to both. The well in which the suction-pipes are placed is 14 feet by 6 feet by 15 feet deep, and the chamber in which the various working-parts are situated is 20 feet high by 14 feet square. The clacks are of double beat type, grathed with gutta-percha, and are arranged in nests of 7, each clack being 9 inches in diameter with a lift of $\frac{1}{2}$ inch. The rising main-pipe is secured to the shaft-buntons, 10 inches square, at intervals of 25 feet, by collaring-buntons 8 inches square. The whole of the pumps rest on five steel girders, $2\frac{3}{4}$ feet in depth (See Fig. 12, Plate X.).

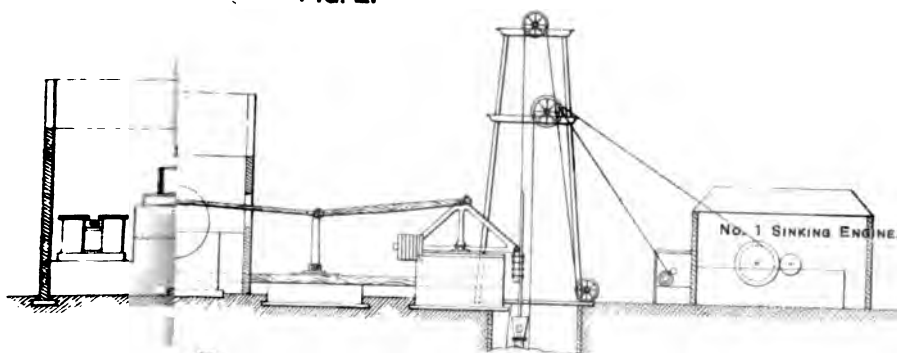
The crab-engine, used for lifting the various pumps and other heavy weights, was of the following dimensions:—Cylinder, 8 inches in diameter by 16 inches stroke; drum, 6 feet in diameter; geared at the worm, 30 to 1; intermediate shaft geared $4\frac{1}{2}$ to 1; and second shaft geared $7\frac{1}{2}$ to 1. It can be set to run at 225 revolutions to 1 of the drum, or at 1,012 to 1 of the drum, and is capable of lifting a weight of 60 tons.

The ram-pumps are capable of raising 2,500 gallons of water per minute to a height of 327 feet at a speed of 8 double strokes, or 160 feet of piston speed per minute.

The brockwell seam was reached at a depth of 395 feet without any further mishap.

The water below the level of the ram-pumps (which are at the three-quarter seam level) is raised to the ram-pumps by means of a tail-bucket sett of pumps attached to one of the ram-pump spears lifting 96 feet, the bucket being 18 inches in diameter, and 10 feet stroke. Provision has

FIG. 2.



ELEVATION OF WINDING-ENGINE, WITH TEMPORARY PUMPING ARRANGEMENT, &c., NO. 1 SHAFT.



BOGIE

**DELIVERY-PIPE
2 OR
NO SHAFT**

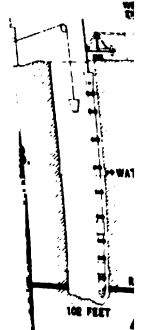
Scale, 32 Feet to 1 Inch.

PLAN OF SURFACE ARRANGEMENTS.



North

No. 1 SHAFT.



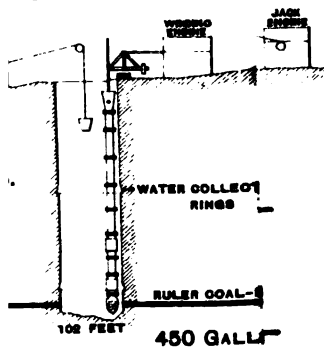
No. 1 SHAFT.



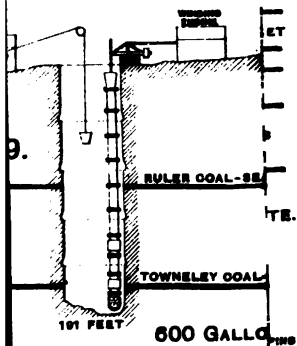
No. 1 SHAF



No. 1 SHAFT.



No. 1 SHAFT.



No. 1 SHAFT.

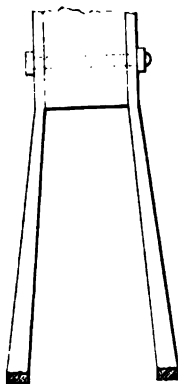
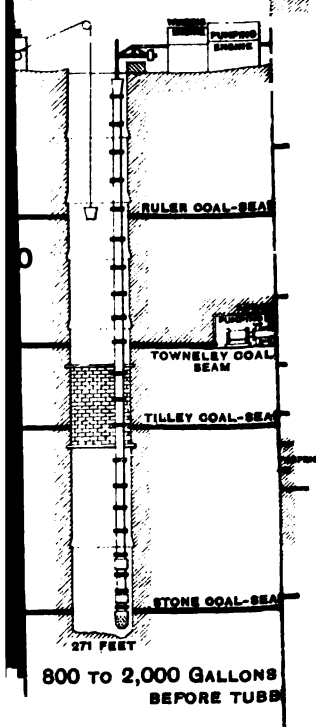


Fig. 18.

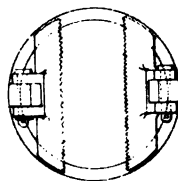
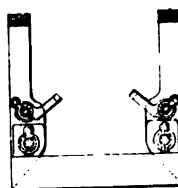
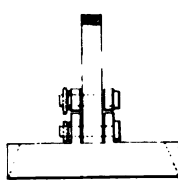


Fig. 15.



Fig. 14.



SPEAR-CATCHER.

Fig. 16.

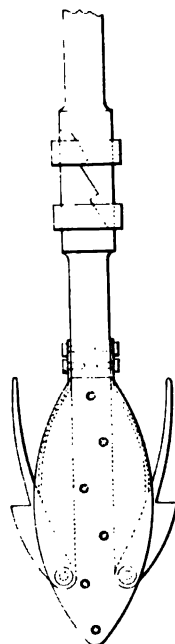


Fig. 17.



CLACK-DRAWER.

Scale, 2 Feet to 1 Inch.

also been made for the addition of a second tail-pump, should the feeders below the ram-pumps require such assistance. When the two tail setts are in use they will raise 1,770 gallons per minute up 96 feet, making a total of 300 pump horse-power.

When the sinking had been completed, it was considered expedient to erect underground on a level with the main ram-pumps a duplicate pumping-engine to meet contingencies, and capable of raising 1,500 gallons per minute when running at 24 strokes per minute. This engine has two cylinders, each 28 inches in diameter by 4 feet stroke, working rams 14 inches in diameter into a rising main-pipe 12 inches in diameter. The engine is of the duplex (quadruple acting) type, working with steam, whose pressure at the engine is about 70 lbs. per square inch.

The total capacity of the two pumps, in case of emergency, reaches 4,000 gallons per minute, leaving a margin of 2,900 gallons over the average feeder, which has been found to be roughly 1,100 gallons per minute.

As the reserve engine is intended simply to be used in case of a serious breakdown of the permanent pumping-engine, economy of steam was not considered essential, and therefore the high-pressure type was adopted as being cheaper in first cost.

Figs. 13, 14, and 15 (Plate X.) illustrate the spear-catcher, as used to recover broken spears of the 24 inches sett of pumps, and Figs. 16 and 17 represent the clack-drawer.

The writer regrets that he is unable to give any satisfactory particulars as to the coal consumed per indicated horse-power per hour, it being impossible to obtain sufficient water to keep the pumps going more than half-speed for any length of time.

The whole of the sinking of these pits was successfully carried out under the superintendence of Mr. J. B. Simpson, managing partner of the Stella Coal Company, assisted by Messrs. Archbold and Pedelty, engineers, and Mr. W. Rochester, colliery manager, and it is owing to the courtesy of the Stella Coal Company that the writer has been enabled to collect the information necessary for this paper.

The CHAIRMAN moved a vote of thanks to Mr. Simpson for his descriptive paper, which would prove very useful to the members.

The motion was agreed to.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND
MECHANICAL ENGINEERS.

STUDENTS' MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
APRIL 10TH, 1897.

MR. G. P. CHAPLIN IN THE CHAIR.

Mr. G. P. CHAPLIN read the following paper on "Cornish Methods of Mine-timbering":—

CORNISH METHODS OF MINE-TIMBERING.

By G. P. CHAPLIN.

The writer regrets that the descriptions of the various ways in which timber is set up have not been collected from over a large area, as the heading would imply, but have been obtained from observations, principally from a single mine. This, however, is one of the largest, if not the largest metalliferous mine in Great Britain, and is worked, owing to its size, under the most varying conditions. In it all kinds of timber and timbering can be seen, from light props, such as are mostly seen in coal-mining districts, to the large timber sometimes 2 feet square and 30 feet long, used for timbering the stopes, or working-places, in the lower levels, which are from 2,000 to 2,600 feet below the surface.

The principal divisions into which mine-timbering may be divided are, (1) shaft-timbering, (2) timbering of levels and cross-cuts, and (3) timbering of working-places. The country-rock in which the tin-lodes of West Cornwall occur, consists entirely of granite of Carboniferous or post-Carboniferous age, with perhaps the exception of the stanniferous veins of St. Agnes, where the country-rock is mainly killas, or clay-slate, which is of Devonian age.

One of the consequences of the granite country-rock is that there is no approach to ground of a loose nature, though in a few places the levels have

to be protected, owing to the granite being sometimes locally very much jointed, necessitating lagging and packing in such places ; but with this exception, the vein-walls are usually strong, and generally can be kept open by supports placed at intervals, varying according to the size of the excavation and the strength of the walls.

Another consequence of the strong walls is that there is little or no difficulty in making strong and suitable seatings or niches for holding both ends of the timber in shaft-work, and the lower end of the timber in levels and stopes.

Shaft-timbering.—It is very exceptional to see a perpendicular shaft in a Cornish mine : as, after being sunk for a greater or less distance vertically until the lode is cut, the shaft then follows the varying directions of the lode, usually proceeding on the foot-wall of the vein, which is very seldom straight for any distance.

The shafts are of such a shape, probably because, in the first place, they were intended only for exploring-shafts to prove the lode, and they were continued as exploring-shafts until they were taken to such a depth that it would have required a large amount of capital to have sunk a new perpendicular shaft, or to have enlarged the old one. Further, the price which could be obtained for tin in the old days did not necessitate the cutting down of expenses connected with getting, hauling, and raising the ore to such an extent as does the price which rules to-day ; and in addition the short-sighted cost-book principle encouraged the production of the largest possible amount of immediate returns with the smallest possible outlay, without seriously looking after the future. This policy, and the low price of tin prevailing at the present day, are to blame for the stagnation of mining in Cornwall.

If tin-mining be continued, these things will probably be rectified, as shown by the latest example of shaft-sinking—i.e., the new shaft at the Dolcoath mine, near Camborne, is a circular, $18\frac{1}{2}$ feet in diameter “down-right” or vertical shaft, which will, it is expected, when finished, cut the main lode at a depth of about 2,500 feet. The writer has nothing to say in the present paper concerning this shaft, as it is bricked in the ordinary way.

Ordinary shafts vary somewhat in size ; but, in an average shaft with a double skip-way, the dimensions are about 11 feet by 5 feet in a right-angled section. The underlay part of this shaft, to the extent of 8 feet, will be taken up by the double skip-way, and the remaining 3 feet, when the excavation is of the full width, is occupied by the ladder-way. If the

shaft be one in which there is a single skip-road, the dimensions will be about 8 feet by $5\frac{1}{2}$ feet, the skip-way taking up 5 feet and the ladder-way about 3 feet; and in this case a somewhat larger skip is used than that employed when a double skip-way is used.

In the downright or vertical portion of the shaft, the area of the section will be greater, principally in the direction at right angles to the plane of the skip-way, in order to give more room for the ladder-road, so as to allow the ladders to be set at an angle to the vertical, as the mining regulations do not allow of a permanent shaft ladder being set in a vertical position; but these regulations do not specify at or about what angle the ladders are to be set, and as a consequence ladders set at angles of 2 and 3 degrees from the vertical may frequently be seen. In this respect the Belgian regulations are superior to the British, since they allow no ladder to be set at a smaller inclination from the vertical than 10 degrees; and this might be increased with advantage to 15 degrees, especially if the ladder-ways are extensively used, as is still the case in some Cornish mines, where ladders are the only means that the miners have of reaching and leaving their work.

Figs. 1 and 2 (Plate XI.) show a section of a shaft with a double skip-way *A* and a ladder-road *B* in the vertical or "downright" and underlay parts of the shafts respectively. In Fig. 2, the section is taken at right angles to the direction of the shaft.

In Fig. 1, the shaft is secured by an outside frame or sett, generally made of timber 8 or 10 inches square, having the wall-plates and the end-pieces joined together by halving the adjacent ends into one another. In some cases, the ends of the wall-plates, and in others the ends of the end-pieces are left projecting past the sett, in order that they may fit into hitches in the rock so that some of the dead-weight of the shaft-work may be taken up. Such setts are called "horned setts," in order to distinguish them from "plain setts." At and near the surface, and in other parts that require it, the setts are placed closely together, with a board-lagging behind, the setts being kept apart by distance-pieces or studdles.

The distance apart of the frames depends principally on the nature of the ground, but is generally fairly regular, *i.e.*, the distance apart of successive frames will only differ by a few inches.

The cross-pieces which divide the shaft, usually 6 inches square, carry the two guides or runners of the skip-way, also 6 inches square, bolted on each side as shown in the figures.

The ladder-way, boarded-off from the skip-way, is provided with platforms or sollars at varying intervals, which must not be more than

60 feet apart, though in vertical shafts this maximum distance apart, fixed by law, is generally less, and depends on the conditions as to width, etc., prevailing at any particular place in the shaft. The distance apart of the sollars, which is perhaps more often found than any other, being 24 feet; the ladder usually consists of two 14 foot lengths joined together, so that when placed in position 4 feet of the ladder projects above the upper sollar. The sides of the ladders are of timber, 2 inches by 4 inches, and the rungs of $\frac{5}{8}$ inch or $\frac{3}{4}$ inch iron bars placed 10 inches apart. Two 14 foot lengths of ladders are joined together either by iron straps, or more often by wooden slats and spikes: the lower end of the ladder resting upon the lower sollar, and the upper end being fastened to the upper sollar by staples; and the ladder is prevented from swaying, if necessary, by stays from the shaft-timber. In underlay shafts, the ladders are laid on the foot-wall, and follow the course of the shaft. The man-holes, through the sollars, are usually from 2 feet to $2\frac{1}{2}$ feet square, and when the ladder-way goes through a level, the man-hole is covered by a hinged iron plate, $\frac{1}{2}$ inch thick.

In underlay shafts, the skip-runners are laid on timber, 6 inches square, set across the foot-wall of the shaft like sleepers, at varying distances, generally from 5 feet to 8 feet apart. Back-runners are not used unless the shaft is very tortuous, or unless a gig is used for lowering and raising the workmen. When back-runners are used, standards are put in, and the back-runners fixed to them in the same way as the runners in a vertical shaft.

In most mines, plain wooden runners about 6 inches square are used, but in a few cases the under-runner in an underlay shaft is protected by a strip of iron, 6 inches wide by $\frac{1}{2}$ inch thick.

In some shafts, having a double skip-road, after a little more than half the depth of the shaft has been traversed, the two tracks merge into one and the shaft can then be made narrower.

At each level, where skips are loaded, the track is made for a few feet or so, as nearly vertical as possible, in order to facilitate loading, and when a skip is being loaded in any upper level, iron doors are shut down over the skip-way in the level immediately below.

The skip used in the shaft of the above-described dimensions was 2 feet 2 inches square by $6\frac{1}{2}$ feet long, and was run at a speed of about 12 miles per hour. When raising workmen, a gig was used (instead of the skip): it had two decks, was 18 feet long, and carried eight workmen at a time, four in each deck.

The shaft-work is kept in repair by the shaft-men, who vary in

number, according to the length and size of the shaft, and according to what fresh work is being done in the shaft. The usual number of shaftmen for a shaft from 2,000 to 2,500 feet long varies from 2 to 4. One of the shaftmen traverses the shaft each day, and notes any place that requires repairing. The gang, as a rule, works during the day-shift only, and receives slightly higher wages than ordinary timbermen, shaft-work being nearly always very wet.

Timbering of Levels and Cross-cuts.—Levels are supported, when the surrounding ground is weak, by the Cornish sett (Fig. 3, Plate XI.), which consists of two legs, a cap, and a sill, the usual lengths of the various parts of the sett being—legs, $6\frac{1}{2}$ feet; caps, 3 feet; and sill $5\frac{1}{2}$ feet; the legs being set with a bevel of $1\frac{1}{4}$ inches to the foot. Although these are the usual measurements, these sizes are by no means always maintained, as in hard ground it is much easier to make the support fit the excavation than to make the excavation fit the support. The sill, or sole-piece, is very seldom used, except in the case of very soft ground, and then the legs are fitted into the sill, as shown in Fig. 4; but usually the legs are simply stepped into hitches cut in the rock to receive them. In Fig. 3, the joint of the cap and legs is chiefly intended to resist downward pressure. In cases where lateral pressure is the greatest, the joint is modified, as shown in Fig. 4 (Plate XI.). Where one wall alone is weak—as is sometimes the case when the level is driven on one of the walls of a wide lode—one leg and a cap only are used, as shown in Fig. 4.

In cases where a level is driven in a fairly narrow vein with strong walls, in an ore that yields much deads or attle, a cap only is used, cut a little longer than the width of the lode, and fitted into a hitch in one wall only, the other end being driven firmly against the other wall with a heavy sledge-hammer. Above this cap, a covering of planks is placed, and the deads are stowed above, as shown in Fig. 5 (Plate XI.). The cap does not require to be strong enough to bear the total dead-weight of the overlying attle, as, in packing, part of the weight is sustained by the walls. Usually, the cap is made strong enough to support two-thirds of the full weight of the superincumbent attle. In such cases (as shown in Fig. 5) round timber is often used; but in ordinary setts timber is almost universally employed from 6 to 8 inches square, or even thicker, according to the weight which it has to sustain. Sole-pieces, when used, are usually lighter than the rest of the sett.

In a nearly flat lode—with a strong hanging-wall that needs supporting—disused iron pump-barrels are occasionally used, and are found to answer

very well against heavy pressures if they are in one length ; if, however, they are made of two lengths bolted together, they are not found to act so efficiently. Pump-barrels are always placed so that the bottom flange rests on the floor, or foot-wall, and wedges are driven in between the top flange and the hanging-wall so as to sustain the weight. When old pump-barrels are not used, which is very often, round sticks of timber *a* are used in a similar manner, as shown in Fig. 6 (Plate XI.).

In the case of a practically vertical lode, from which the ore has been all wrought, the tramways are carried on pieces of timber placed similarly to the cap shown in Fig. 5, but with more regard to the horizontal position of the timber (Fig. 7, Plate XI.). On such stulls, a plank floor is laid, which is seldom tightly jointed, as slab-planks are usually employed, and as a consequence pieces of ore frequently fall from the trams of one level into the level below.

The writer has seen one case, which he believes to be uncommon, where, as one wall was weak and did not afford good holding-ground for the stull, one end was supported by a chain suspended from a bolt which had been placed in a large bore-hole, and wedged tight, the other end of the stull being placed in a niche in the country-wall in the ordinary manner. This method was found to act very efficiently, as the free end of the stull was wedged up to the wall so as to keep it from swinging.

Stulls are generally put in at distances from 6 feet to 8 feet apart, and their size depends on the weight which they have to support. They are always made of squared timber.

Sometimes levels may be seen which are protected, as shown in Fig. 8 (Plate XI.), by a cross-piece *a* being placed from the foot of the level to the opposite wall, and lagging or lacing is placed upon it, which keeps the *débris* out of the level. If the hanging-wall be weak, an extra piece *b* is placed from the other side of the level to the cross-piece, as shown ; this timber is also lagged and has small deads packed behind it to resist the pressure. This mode of protecting a level is only seen when the lode is inclined and fairly wide. Squared timber is always used where the span is large and the strain great ; and round timber is used where the ground is harder and where the hanging-wall does not put so much strain upon it.

In the case of narrow veins, which produce no deads, and which have strong walls, the vein is kept open by stulls placed at right angles to the walls, wherever they are thought necessary ; their positions with regard to each other being anything but regular.

Timbering of Working-places.—In the case of narrow and highly inclined veins, yielding an ore which gives a considerable amount of deads, practically no timber is used except that required for the mills or shoots. These shoots are more or less vertical openings made through the deads to the level below; into which the ore is dropped. The shoots are generally placed so that the whole of the mill is to one side of the tram-line in the level below. The bottom of the shoot is made sloping towards the tram-line, and is usually covered with an iron plate *B* ($\frac{1}{2}$ inch thick), a piece of old boiler-plate being often employed. The area of a section of the lower part of the mill is usually slightly greater than the area of a section at the top, in order to prevent large pieces from lodging and jamming. The ore is withdrawn into trams through an opening *C* in the side next the level (Fig. 9, Plate XI.), and when ore is not being withdrawn, this opening is kept closed by short pieces of plank placed through long staples which are driven into the standard timbers in the level.

These shoots are generally very roughly constructed, and are made to suit the peculiarities of the particular place in which they happen to be built. Shoots are generally square in section, and are kept together by frames of timber *D*, 6 inches square, placed at wide intervals apart, and the lagging is spiked vertically to the inside of these timbers. The lip at the bottom of the mill is made to project into the level, so that, when the tram is underneath, the lip clears the top of the tram by about 2 inches, and projects over the tram from 2 to 4 inches, in order to facilitate loading.

In cases where the mill is built touching one wall of the vein, as shown in Fig. 9, one side of the frame is dispensed with, and the vein-wall is allowed to form the fourth side of the shoot.

In a few cases, the part of the shoot through the deads is made circular, and is built up of round pieces of attle. This method is found to answer efficiently if the shoot be not too long.

In some of the large mines of the western states of the United States of America, where the distance between levels is great (from 200 to 400 feet), it is found that lagging, placed as above described, will not stand the action of ore falling from so great a height, and the shoots are consequently built of square pieces of timber, placed so that the end of the grain is towards the inside of the shoot.

With large lodes, that leave no deads, heavy squared timber is required in order to keep the vein open. The ore is usually got by overhand stopping, as the roof has then new surfaces constantly exposed, and there is

much less likelihood of a run occurring than with a roof which has been left for some time, and where the air has had an opportunity of penetrating the cracks and crevices and making the roof dangerous. The roof also being constantly under examination, its condition is better known, and possible dangers may be more easily prevented.

When work is started in large places, the ground is stoped away as far as possible by means of temporary platforms fixed on ladders, etc., and when this system has become impracticable, a stull, *a* (Fig. 10, Plate XI.), is inserted, and a leveller, *b*, will be put in position, as shown in the figure. If the leveller be long, a studdle, *c*, is inserted underneath it, though studdles are usually put in for convenience and not for strengthening purposes. A platform or sollar *d* is then erected across the levellers, and a fresh surface to work from is obtained. When the walls are strong, this process is repeated as the ore is stoped away, the foot of the next stull resting on the leveller below it, and the next leveller being ranged from the top of this stull to the foot-wall as before, a studdle is then put in and a second working-platform is obtained; and this process is repeated as often as necessary. When, however, the hanging-wall is weak, auxiliary stulls have to be inserted as at *e*, the lower end being slightly checked into the leveller, and the top end wedged in the ordinary way.

Stulls are placed nearly at right angles to the vein-walls, the lower end being placed in a hitch cut in the foot-wall, and the top end is wedged up to the hanging-wall. The stulls are usually placed close together at distances varying according to the nature of the ground from 2 feet to 4 feet or more apart from centre to centre; their length varies with the width of the stope, sometimes being nearly 30 feet long; and their thickness depends on the strength required, being sometimes used as much as 22 inches square, although the average dimensions are 16 inches square. The levellers have one end placed in a hitch in the foot-wall, and the other end is bevelled to rest on the stull. The studdles are generally not quite as long as the stulls, nor quite so heavy, their average thickness being 12 inches square.

The stulls are always left after the ground has been worked out, but the studdles and levellers are, when possible, removed and used over again.

The handling and setting up of this timber is heavy work and is generally undertaken by a gang of from 8 to 15 workmen, according to the size of the timber, which is hove into position by a pair of three-sheaved blocks and rope-tackle.

When rises are being made—usually driven on the foot-wall—plat-

forms are inserted at intervals, for the workmen to stand upon whilst working the drilling-machines. These platforms generally consist of two stulls put in about $4\frac{1}{2}$ feet to 5 feet apart very firmly inserted, as they have to withstand a good deal of rough usage whilst the drill-holes are being fired, and if one or both stulls are knocked out, the machine-men are idle until they are replaced. The stulls usually employed consist of round timber about 8 inches in diameter, planks are placed between, slightly longer than the distance apart of the stulls, thus leaving a space at each side of the rise to allow of the blasted rock falling into the level below. As the rise proceeds upwards, some of the excavated material is left on the platform, and the workmen stand on this *débris* until the pile will no longer remain firm, and the face of the rise is too far up to be conveniently worked, then two more stulls, with a platform, are inserted, and the stulls first fixed are removed to be used again.

General Remarks.—The tools used in timbering are few and simple. All large timber is cut on the surface to measurements given by the head-timberman; these measurements being taken very accurately, as any mistake of more than 1 or 2 inches would involve considerable loss in time and material in cutting the stick to fit the place if too long, or in using at some other place if cut too short.

The measurements are taken with a staff, which consists of two pieces of board, 3 inches wide by 1 inch thick, and of a length suitable to the general width of the lode where it is being used—10, 12, and 14 feet being the most general lengths. One piece has two collars of iron fixed to it, one at one end of the piece, and the other about 2 feet away: these collars are made just large enough to allow of the other part of the staff sliding through, thus making the two parts of the staff into one length, which length can be varied as the free part of the staff is slid up or down through the collars. In order to keep the staff at the required length, when a measurement is being taken, the inside or lower collar is tapped, and a $\frac{1}{2}$ inch clamp-screw is inserted on the side of the collar which holds the free part of the staff: this has a groove of $\frac{1}{2}$ inch wide by $\frac{1}{4}$ inch deep, planed down its length, in which the clamp-screw travels. When a measurement is being taken, one end is set on the floor and the free end is run up until it touches the roof or hanging-wall, it is then clamped, taken down, and the length measured.

For taking a large stick from the shaft-bottom to the place where it is to be put up, a simple pair of tram-wheels is used, the stick being balanced on the axle and then run in by the timber-gang.

With the smaller round timber, used for props or short stulls, etc., less accuracy is observed in the measurements, and they are cut down with a hand-saw or hatchet (commonly called a "dag"), or, very occasionally with a cross-cut saw, to the required length; they are then raised into their places, wedged, and driven tight with a heavy sledge-hammer, as are the large square sticks.

The material used is pitchpine, costing about 2s. per cubic foot, delivered at the mine, for the square timber, and Norway fir costing 6d. per cubic foot for the round timber.

The cost of timber for every ton of ore raised is difficult to ascertain, as in the mine accounts it generally comes under the head of maintenance, in which are included many other costs connected with the mine. At Carn Brea mine, however, the cost of timbering is kept separately, and amounts to 2½d. per ton of ore raised. This may be taken as a fair average cost for most of the mines of Western Cornwall, and with this cost may be contrasted the cost of timbering at the Broken Hill mine in Australia, viz., 6s. 10d. per ton of ore raised.

Old timbers are never taken out until they fall out; if any piece of timbering be condemned as weak or unsound, other props or setts are put in on each side of the faulty piece and wedged to take up the weight.

The life of the timber is short, being, for Norway baulks, from two to three years, if the timber is in a dry place, and rather longer if the stick is constantly wet; but pitchpine lasts rather longer as a rule.

Practically, no steps are taken to preserve the timber, although sometimes a few setts may be treated with a coating of boiled tar, which prevents fungi from attacking the setts for a slightly longer time. This treatment has not, however, come into favour, as the tar is very hard on the hands of the workmen when setting timber. Another method of treatment has been recommended by one authority on timbering, viz., that of giving the timber a coating of cheap liquid cement; but, so far as the writer is aware, this method has not yet been tried in Cornwall.

It is probable that the treatment of timber described by Mr. Robert Martin* might be practised with distinct economy on Norway fir; as might also the processes of charring and of steeping in sulphate of iron; and, perhaps, even the processes of kyanising or burnettising; though pitchpine would probably not be benefited to so great an extent on being treated, owing to its denser nature.

The question as to the economy of treating mine-timber is a very

* *Trans. Fed. Inst.*, vol. x., page 532.

large and important one, and it is to be hoped that in the near future experiments will be made to test the value of the various methods. Such experiments, if properly and systematically carried out, would be of the greatest importance, but at the same time it must be remembered that for any evidence so gained to carry any weight, the timbers which are being compared must be placed where they will be affected by the same conditions. Further, conclusions should not be drawn, as is too often the case at present, from the comparison of an isolated sett or prop which has been treated and erected in one part of the mine, with a similar sett or prop elsewhere, where the conditions may be different.

Wherever possible, it is recommended that arches of the vein should be left here and there between the separate levels, especially where the ore is poor, as ore that would only just pay to take out would often save the expense of timber. These arches can be taken out when the lode has found its bottom, and work is started upwards, the lowest arches being removed first. In size, arches should never be less than 24 feet along the length of the vein, and 30 feet high, especially where the arch is likely to become smaller through air getting into the crevices of the rock and breaking pieces off.

On account of the harder nature of mineral veins as compared with coal-seams, a very much smaller shaft-pillar is required—tinstone being often taken away up to within 24 feet of either side of the shaft. Stopping is usually not started at quite so short a distance, but is generally started from a rise or winze connected with a level above or below, which rise or winze is usually not nearer than 120 feet to the shaft.

Mr. R. O. BROWN moved a vote of thanks to Mr. Chaplin for his paper, which was agreed to.

FIG. 3.

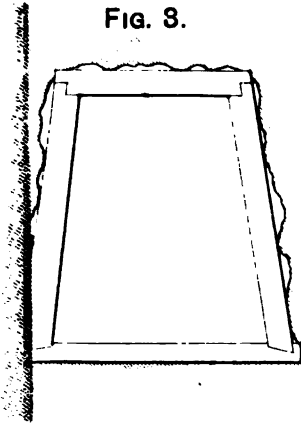


FIG. 4.

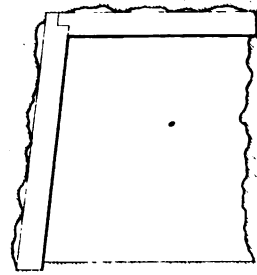


FIG. 6.

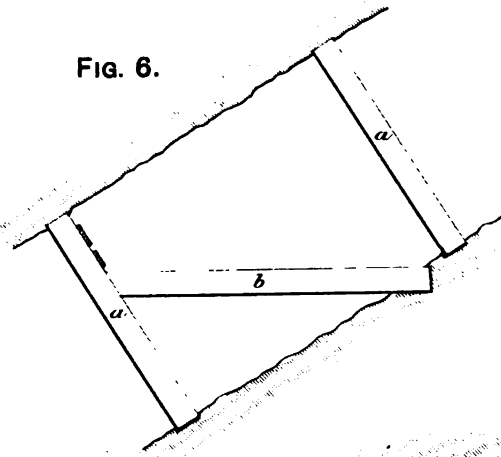
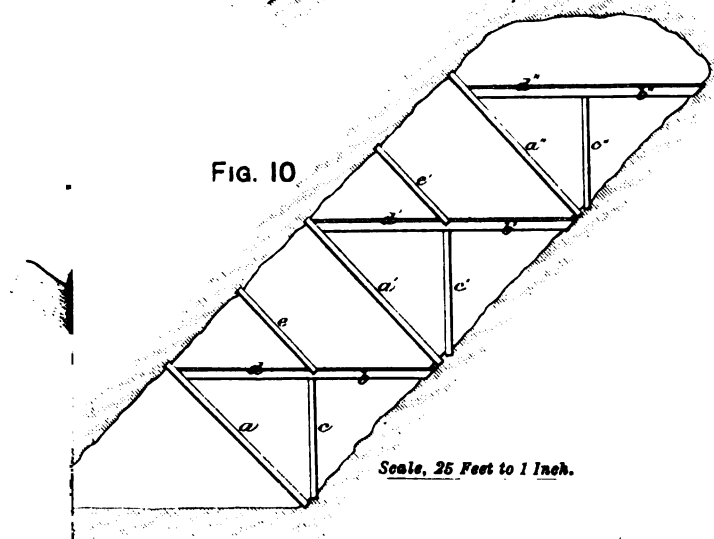


FIG. 10



Scale, 25 Feet to 1 Inch.

North

THE MINING INSTITUTE OF SCOTLAND.

ANNUAL GENERAL MEETING,
HELD IN THE HALL OF THE INSTITUTE, HAMILTON, APRIL 15TH, 1897.

MR. GEORGE A. MITCHELL, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The SECRETARY read the report of the Council as follows :—

COUNCIL'S REPORT.

The Council, in presenting the nineteenth annual report of the Institute, have pleasure in stating that fair progress has been made during the past year.

The number on the roll has been reduced by 13. The particulars are as follows :—

On the roll at April, 1896	...	...	...	492
Added during the year	...	...	...	23
				515
Died	...	...	...	6
Retired	...	...	...	4
Cut off through non-payment of				
subscriptions	...	...	...	26
				36
On the roll at this date	...	...	...	479

The number taken off the roll by death and otherwise is not more than the average of the last twelve years, but the number of additions is smaller than usual. This difference points to the desirability of members doing what they can to get new members, in order that the number on the roll may be maintained and, if possible, exceeded.

Of those on the roll at this date, 420 are federated and 60 non-federated, as compared with 411 and 81 respectively at the corresponding period of last year. The decrease in the number of non-federated members is due partly to transference to the federated list ; and as the

value of the *Transactions* of The Federated Institution of Mining Engineers becomes better known the members still non-federated will no doubt desire to have their names transferred.

Of those who died during the year, special reference must be made to Mr. Ralph Moore. The following is an excerpt from the minute of a meeting of Council held on January 21st, 1897 :—

The Council agreed to record their sense of the loss which the Institute had sustained through the death of Mr. Ralph Moore, Her Majesty's Inspector of Mines (retired), and an ex-President of the Institute. From the foundation of the Institute in 1878, Mr. Moore took the liveliest interest in its affairs ; and as President for four years, from 1879 to 1883, did much to establish it on a firm footing and to widen the sphere of its usefulness. He continued to retain a close connexion with the Institute, being at the date of his death one of its representatives on the Council of The Federated Institution of Mining Engineers. The Council gave expression to their sincere sympathy with Mrs. Moore and her family in their bereavement, and instructed the Secretary to transmit to her a duplicate of this minute.

The Council feel assured that the Institute approve of their action in this matter and endorse all that has been expressed in the foregoing minute with reference to Mr. Moore.

The papers read during the year and published along with the discussions thereon are as follows :—

“The Duty of Pumping Engines.” By Mr. Dugald Baird.

“The Health Conditions of Coal-mining.” By Mr. James Barrowman.

“The Causes of Death in Colliery Explosions.” By Dr. John S. Haldane.

“The Mineral Seams of New Monkland.” By Mr. James Prentice.

“Sinking, Surface Fittings, and Coal-cleaning Plant.” By Mr. James Hastie.

The Council regret that more papers were not placed at their disposal ; and they take this opportunity of asking the members generally to make some effort to provide papers.

The annual excursion took place in September last to South Wales, coincident with the meeting of The Federated Institution of Mining Engineers at Cardiff. An opportunity was afforded of visiting some of the collieries and other important works in the neighbourhood of Cardiff. The number of members who could take advantage of the excursion to such a distance was necessarily limited, but those who took part enjoyed the excursion.

On the application of the Council, the Institute has been admitted a corresponding society of the British Association for the Advancement of Science. This position secures to the Institute the annual report of the proceedings, and requires the attendance of a delegate from this Institute at meetings of the Association. A representative from the Council attended

one of two conferences of the Corresponding Societies Committee at the Liverpool meeting in September last, when a proposal was submitted for forming district unions of Natural History Societies, somewhat similar as regards these societies to The Federated Institution of Mining Engineers in relation to the several mining institutes. At the second conference the subject of the appointment of a federal staff for local museums was under discussion. Neither of the two subjects of conference touches the work of this Institute, and the Council do not propose to take any action with regard to them.

The donations received during the year are as follows :—

DONORS.	DONATIONS.
Mr. George A. Mitchell ...	£5 13s. for Books for the Library.
Mr. J. T. Robson ...	Report on Tylorstown Colliery Explosion.
Mr. J. M. Ronaldson ...	Inspectors' Report for West Scotland, 1895. Report on the Causes of Death in Colliery and Under-ground Fires, by Dr. Haldane.
Mr. B. T. A. Bell ...	The Canadian Mining, Iron, and Steel Manual, 1896.
Mr. Wm. Galloway ...	Coal Dust : The Question of Priority.
Messrs. Crosby Lockwood & Co.	Messrs. Bulman & Redmayne's "Colliery Working and Management."
Mr. T. V. Holmes ...	Notes on the Whitehaven Sandstone. Notes on the Best Locality for Coal beneath the Permian Rocks of North-west Cumberland.
Literary and Philosophical Society of Liverpool ...	Transactions, 1895-96.
Mr. Bennett H. Brough...	Mining at Great Depths.
West of Scotland Iron and Steel Institute ...	Journal, Nos. 2 and 3, vol. iv.
Mr. Jeremiah Head ...	The Manganese Ore Deposits of Northern Spain.

Further additions have been made to the list of exchanges, which now numbers over 50. The Transactions and other publications received in this way form a most valuable store of information on all departments of mining and allied industries.

There have been eight meetings of Council during the year.

The adoption of the report was agreed to unanimously.

The SECRETARY read the following abstract of the Treasurer's accounts for the year :—

The following gentlemen were elected :—

MEMBER—

Mr. THOS. MITCHELL, Crossmount, Bridgend, Perth.

ASSOCIATE MEMBER—

Mr. JACKSON RUSSELL, Auchinraith, Bothwell.

ELECTION OF OFFICE-BEARERS.

The PRESIDENT declared the following office-bearers duly elected for the session 1897-98 :—

PRESIDENT.

Mr. GEORGE A. MITCHELL, 5, West Regent Street, Glasgow.

VICE-PRESIDENTS.

Mr. JAMES HASTIE, Greenfield Colliery, Hamilton.

Mr. WALLACE THORNEYCROFT, Merryton Colliery, Hamilton.

Mr. JAMES T. FORGIE, Bothwell Collieries, Bothwell.

Mr. JAMES HAMILTON, 208, St. Vincent Street, Glasgow.

COUNCILLORS.

Mr. THOMAS ARNOTT, Fernbank, Newton.

Mr. ALEXANDER FAULDS, Steel Works, Calderbank, Airdrie.

Mr. JAMES GILCHRIST, Lanemark Colliery, New Cumnock.

Mr. JAMES HARDIE, Broomknowe, Cambuslang.

Mr. DOUGLAS JACKSON, Coltness Iron Works, Newmains.

Mr. JOHN MENZIES, Auchinraith Colliery, Blantyre.

Mr. HENRY TELFER, Birkhill, Uddingston.

Mr. THOMAS THOMSON, Eddlewood Colliery, Hamilton.

Mr. MICHAEL ROSS, Bog Colliery, Larkhall.

Mr. DAVID SMITH, Dalmellington Iron Works, Ayr.

Mr. JAMES WALLACE, Wester Gartshore Colliery, Kirkintilloch.

Mr. JAMES WYPER, Townlands Colliery, Hamilton.

The PRESIDENT then delivered the following address :—

PRESIDENTIAL ADDRESS.

By G. A. MITCHELL.

There has been a considerable amount of legislation during the past year affecting mining in various ways, but by far the most important of the various enactments has been the new order in connexion with the use of explosives issued by the Secretary of State for the Home Department. The order has been so unexpected, and colliery owners have been so unprepared for the radical changes which it proposes to introduce, that there is little information available to show with certainty what the effects of the order will be. Various statements have been made, more or less contradictory, and your Council, with the view of testing the actual position of matters in Scotland, appointed a committee to consider the order. A few preliminary experiments have been made, and the results of these are to be shortly submitted to the members.

Meanwhile we must reserve judgment as to the effect on costs, which must necessarily differ in different districts and in different collieries in the same district. It may be said, however, that there is a general feeling that the order is more stringent than is necessary to meet all the circumstances of the case, and specially, that the prevention of the use of gunpowder in collieries where open lights are in use, as may be the case under the order, seems to be somewhat unreasonable. In such a colliery, where the roads are not dry and dusty, there can be no more danger of an explosion from the use of gunpowder than from that of open lights. If it is not only explosions of dust and gas which are considered, but possible accidents which might arise from the use of powder in conjunction with open lights, the remedy would appear to be, not the prohibition of the use of powder altogether, but strict regulations for its use and for the kind of fuze to be employed. It would not appear, however, that such accidents are numerous enough to call for special legislation.

It is to be hoped that the order will be considerably modified when the weight of opinion against it in the country becomes properly known.

There has been much mining legislation in the past generation, and great good has been done by it, but the reduction of accidents cannot be fairly traced in entirety to such legislation.

In other countries, where there are not so many restrictions and such close supervision as in this country, accidents have been reduced also, and much of the improvement in mining conditions everywhere is due to the advance in scientific knowledge and to the recognition of the fact that to have a mine well conducted makes it not only safer but also more profitable.

It is well to realize that legislation may go too far and that accidents may be prevented at too great a cost. The certain way to prevent accidents entirely would be to shut up mines altogether, but such a remedy is not contemplated, and care must be taken that legislation does not proceed in this direction by unreasonably increasing the cost of working without a compensating decrease in the number of accidents.

Even a comparatively small increase in the cost of production may be serious, when other nations are fighting so keen a battle for our foreign markets—and no legislation which adds to this cost should be passed without very good reason.

Every year it becomes increasingly necessary to pay attention to economy in mining, and to-night I desire to speak to you on the importance of accuracy in the attention to details, and specially on the necessity of cultivating what may be called the arithmetical or mathematical faculty in dealing with such matters, or, in other words, the necessity of making the most careful preliminary calculations in connexion with all the details of colliery management, or of submitting everything to the test of figures.

All recognize the necessity for careful calculations, and yet all will admit that it is exceedingly difficult to look at all sides of a question, to think of the various difficulties which may arise, to provide for these, and to adopt the policy which is likely to give the greatest economy and efficiency in any particular case. It is possible to cultivate the critical faculty requisite for making these calculations, and it is very necessary for all engaged in colliery management to do so, whether possessed of great experience or not. It is true that long experience enables many men intuitively to know, with fair certainty, what should be done in certain cases; but even men with long experience may make mistakes, through the want of full consideration, especially as the constant progress of mining science makes it very necessary to consider arrangements in the light of the latest improvements. It need hardly be stated that experience is required in making the calculations.

The necessity for these careful calculations is evident in every stage of the development of a colliery, whether it be the choice of a mineral

field, the choice of the position for the shafts, the fitting up of the machinery, the laying out of the workings, or the conducting of operations when the colliery is started.

Those who have been looking for coal-fields know how difficult it is to form reliable conclusions regarding the value of any particular field. This is so in all cases, but especially if the field is not in a well proved district.

The consideration of the value must take into account the position of the field as regards markets, the quality of the coal, the proportion of round coal to dross, the cost of working at the face, the cost of oncost due to the special circumstances of the field, the quantity of water, the output to be got and disposed of, the cost of sinking and fitting, the lordship to be paid, the cost of management, depending to some extent on the kind of coal to be disposed of.

As the profit on the working of coal per ton is, in average years, small at the best, and as it takes very little to turn an expected profit into a loss, it is evident that very careful calculations are necessary before expenditure is incurred. All the points named are of great importance, and an error with regard to almost any one of them may result in the outlay on an unprofitable subject or the rejection of what might be a fair venture.

The question of the expenditure involved must receive special attention, and it is worth while noting that a colliery where a large output can be got for a small capital may be a profitable undertaking over a series of years, even if it will not pay in bad times.

For example, take two collieries, each capable of producing 120,000 tons per annum of coals of the same value—(1) one which can be worked for a capital of £15,000, and (2) one for which a capital of £36,000 is necessary, the latter having a clear advantage over the former in the cost of working of an average of 6d. per ton, which is a very considerable advantage.

Let the value at the end of 21 years, including working capital of (1) be £6,000, and of (2) £9,000. Allowing interest on capital at 5 per cent. and redemption at 4 per cent., the interest and depreciation on (1) will be £1,081 yearly, or 2·06d. per ton, and on (2) £2,645 yearly, or 5·29d. per ton, being a difference in favour of the former of 3·23d. per ton. And this difference reduces the advantage in working costs to 2·77d. per ton.

Suppose that (1) makes a loss during some years, but makes over six years £6,000, or an average profit of £1,000 per annum, being

£6 13s. 4d. per cent. on £15,000, (2), with the advantage of 2·77d. per ton, will make £14,310, or £2,885 per annum, being £6 12s. 6d. per cent. on £36,000.

This is only a rough illustration, but is sufficient for our purpose. In the circumstances, over a series of years, the colliery with the dearer working would give a slightly better return to the shareholders than the other. Consideration, of course, must be given to the fact that as much energy must be devoted to the superintendence of a concern which gives interest on a small investment as in the case of another where a larger capital is invested. If the companies are limited companies this would not be of any consequence to an ordinary shareholder who held the same amount of capital in both concerns, nor to the managers if the same salaries were paid in both cases. It would be of great consequence to an owner who superintended his own collieries, and who desired to invest as much as £36,000 in colliery property.

The same illustration clearly shows that it may be worth while to pay a large price for a really first-class colliery which yields a good return in bad times as well as in good.

The choice of the position of the shafts for a new field must depend on many things, such as the shape of the field, the dip and rise of the strata, the facilities for railway accommodation, the suitability of the ground for sidings, the position and size of dykes and faults, the quantity of water likely to be met with, etc. It is impossible for any general rules to be framed which will cover all circumstances. Perfect satisfaction with all the points to be considered cannot be got in any case, and all that can be done is, after the fullest consideration of the advantages and drawbacks of the different positions, to adopt the best possible solution of the particular case. Improvements in mining must be taken into account in the considerations which influence a choice in this as in other departments of mining. For example, the successful application of hydraulic and electric pumping-plant of recent years has to some extent overcome the greatest difficulty in connexion with dook workings, and made it not so necessary as formerly to fix the shafts as nearly as possible at the extreme dip of the field. In certain circumstances dook workings may be quite as cheap as rise workings, and in some cases even cheaper. Capital outlay may, therefore, sometimes, be saved by sinking to a less depth than might, at one time, have been considered necessary.

The shape to be adopted for the shafts requires careful attention. It is strange that so few circular shafts have been sunk in Scotland. They have many advantages over square and oblong shafts.

In choosing the machinery to be adopted in fitting up a colliery, attention must be given to many considerations, such as the kind of coal to be treated, the life of the colliery, the probable output, and the nature of the markets to be secured. The calculations to be made must take such things into account as safety, efficiency, first cost, cost of upkeep, and cost of working, and there must be a due weighing in the balances of the different advantages and disadvantages of different suggested arrangements, and, when an arrangement is decided on, all details must be so carefully considered that no part will interfere with any other part. The plant should be thoroughly substantial, so that stoppages through breakdowns may be of very rare occurrence. It is a false economy—even at a great saving—to have plant that gives trouble in this way, as idle days are a source of great loss, and are apt to come at the most unfortunate and unexpected times. The plant must be sufficient for its work and machinery for ventilating purposes must have very special attention.

Perhaps none of the plant about a colliery at the present time is of greater importance or calls for more attention than that for handling the output on the surface, and such plant must vary in different circumstances. The aim should be to secure economy in the cost per ton of output, and also so to prepare the product of the mine that the best possible price can be realized. At one colliery simple plant only may be required, while at another more complicated machinery may be desirable.

There is a growing necessity for the careful handling of coal in all cases, and apparent extravagance in seeking to secure the best result may be well justified.

Take for example a colliery that is being fitted out with the expectation that an output will be got of 450 tons per day, or say, 112,000 tons per annum for 15 years. This colliery might be fitted with old-fashioned screening-plant, at say a cost of £500, or even less, and some engineers might consider this a sufficient sum to spend in the circumstances; or it might be fitted with good screening and cleaning-plant and washer for say £3,500, which seems a large sum until it is put to the test of figures.

The difference is £3,000, less say £500 more to be realized for the machinery at the end of the lease in the one case than in the other. Calculating interest at 5 per cent. and redemption at 4 per cent., £2,500, the extra outlay, is equivalent to £250 yearly; £500, the extra amount to be realized at the end of 15 years, at 5 per cent. interest, equals £25 yearly; extra upkeep per annum, including repairs, fuel, oils, grease, etc., equals say £125—total, £400 yearly. For the output named this

annual amount is equivalent to 0·85d. per ton. There are few circumstances in which such a small difference per ton would not be more than covered by the extra price to be realized by the careful preparation of the coal. No account is taken here of the cost of washing, which must go against the extra price to be got for washed dress. There is, in addition, the probability that a more ready sale will be got. The result of the calculation would be much more favourable for a colliery with a larger output and a longer life.

Of recent years great attention has been paid to the construction of pitheads and to devices for saving labour. That such attention will be amply repaid is plain, when we consider that for a colliery to last 15 years on the same basis as in the last calculation, the saving of one man on a pithead, or £50 per annum, will allow a capital expenditure of £500. Gradients so arranged that four lads at 18s. 6d. per week can do the work of four men at 18s. per week will justify a similar outlay. The saving of a horse, at a cost of say £40 yearly, will allow an outlay on the railways of £400.

Then, as regards the kind of boilers to be employed, the saving of 4 tons of fuel per day for 15 years at 1s. 6d. per ton, or say £110 per annum, less say £30 yearly for extra repairs required, will allow an additional expenditure on boilers and heaters of £800, without taking into consideration the extra value at the end of the period and the saving of labour which results from the smaller consumption of fuel.

Too much must not be spent for economy in working. Take an example from another industry. Triple-expansion engines for steamships are looked upon as a necessity for economical working, and yet it has been contended with much force that for a river steamer, running only for a few months in the summer in a place where coal is cheap it is true economy to save the first cost by making use of the old-fashioned single-cylinder engine, even at the cost of a considerably increased coal-consumption.

According to the same reasoning, in fitting up plant for a small field to last only for a few years with a small output, it may be best to fit up second-hand engines and cheap boilers. Each case must be considered by itself.

Where it is not desired to invest a very large capital in a concern, arrangements may be justified which are not economical. In such a case care paid to the designing of arrangements may make it possible for improvements to be gradually made out of profits or otherwise when it is considered advisable to invest more capital in the concern. Carelessness

in the attention to such details may put the colliery in the position of many which require such radical alterations to put them right that the owners hesitate to spend the money required.

The most careful consideration must be given to the details of all the arrangements in developing the colliery underground, and in the conducting of all the various operations in connexion with the output of coal. Much money may be saved by the careful laying out of pit-bottoms, and for large outputs, a large expenditure may be necessary.

The question of the kind of haulage to be adopted is important, and must be considered in relation to the nature of the roof, etc. The cheapest working haulage may not be the best, if it involves large outlay and heavy expense for upkeep, and, on the other hand, considerable extra first cost in roads and haulage may be justified by subsequent economy in working.

In considering the question of the system of working to be adopted and the laying out of these workings, all available data must be made use of. The comparative costs of working at the face of the different systems, the upkeep of roads, the cost of timber, the output that can be got, all call for consideration in estimating the advantages and disadvantages of each system.

For a large field it may pay well to experiment carefully with the different systems of working, where there is a doubt as to which is best, and the same may be the case in the consideration as to which of two seams should be worked first.

Concentration of output should be aimed at. Perhaps too little attention is paid to this, and it might be of advantage at times to make out cost-statements, not only for different seams, but for different sections of the same seam. It may be necessary to push the output of a small section by putting in extra men, or by double shifting, even at a considerably higher cost per ton at the face, if the cost is high for upkeeping the roads to the section, or for the haulages. If statistics were noted on this point some surprising results would be revealed. The same thing holds when a seam is nearly exhausted and the output small. The oncost becomes high and the cost for timber and other material is excessive. In addition to the general saving on the upkeep of roads and on haulage by concentration of output, there may also be a saving in the cost of the inspection necessary under the Mines Regulation Acts.

In connexion with this point, it may be noted that the saving obtained

by the use of coal-cutting machines, owing to the increased output from the face, may be greater than is generally supposed.

Take as an illustration a case from experience. A road, 1,188 feet in length, cost for upkeep for three months, £7 18s. 6d. for timber and £22 14s. 3d. for wages, or a total average per fortnight of £5 2s. 1d. Owing to the arrangement of workings, the entire length of working-face in connexion with this road is 462 feet. The probable output from this face by hand-labour would be about 500 tons per fortnight, and the quantity that could be worked by a successfully operating coal-cutting machine would be about 1,000 tons for the same period.

The cost of the upkeep of the road on the basis of the actual cost for the three months in question would be 2·45d. per ton for hand-labour and 1·22d. for machine-cutting, showing a saving for the latter of 1·23d. per ton. In addition to this saving there would be the lower cost of haulage in favour of the machine, owing to the larger quantity taken over the same road.

It may be found of advantage to obtain concentration by the driving of cross-cuts between seams even at considerable expense, especially if a road with a good roof can be used for a seam where the roof is bad. By this means one haulage may be made to do the work of two, and, within reasonable limits, the larger the quantity to be drawn by a haulage the cheaper will be the cost per ton. By such an arrangement also, coal may sometimes be worked which would otherwise require to be left in to protect main roads, etc.

As showing the necessity for careful attention to every detail in colliery working an example may be given from experience in connexion with haulage. At Gateside colliery, all the haulage is worked by means of a band-rope from the surface. This band-rope works in all five haulages, two in the ell coal-seam and three in the main coal-seam. In passing down the shaft and from the one seam to the other it goes over in all 14 pulleys, three of which are clip-pulleys, and none of which are less than 6 feet in diameter.

For the first few years after the haulage was started, the rope gave a great deal of trouble, and only lasted from 6 to 10 months. There was so much difficulty experienced in keeping the splice right that it was inferred that there was a great strain on the rope, and a heavy rope was used, it being got four times in succession $1\frac{1}{2}$ inches in diameter. The ropes were got of various qualities, and for 33 months the cost was £358 17s., or £10 18s. 5d. per month. In order to ascertain really

what power was being used, and what size of rope was actually required the engines were indicated. The diagrams showed only about 30 horse-power, when the engines were working with their heaviest load, and, by calculating the strain on the rope, it was evident that a smaller rope ought to do the work. The next rope was got $\frac{7}{8}$ inch in diameter, and of improved steel. Two ropes of this description lasted 26 months, and cost only £63 6s. 5d. or £2 8s. 8d. per month. The saving in ropes therefore, on the basis of these results, has been £101 17s. per annum, and the smaller ropes have done quite as much work as those previously in use. The large ropes were apparently too heavy and stiff for their work, and damaged themselves by their own weight and by going over so many pulleys.

It might be a profitable calculation to consider how far it is wise to use slow speeds for band-ropes, and whether higher speeds, with gearing in connexion with the haulage-machinery belowground, could not be adopted with advantage. Ten miles per hour would not be too fast for a rope to run in a shaft: with such a speed, a very small rope would be sufficiently strong, and probably there would be less wear of the driving-pulleys.

It is a point worth noting that where any expenditure is found desirable with the object of making a saving in working costs, it is best to do the work as quickly as possible. There is often a strong temptation to spread such expenditure over a lengthened period, so that the oncost charges for any fortnight may not be unduly increased. This is not true economy, nor will it be found so when reduced to the test of figures. Take for example an outlay, say on mine-driving, of £200, which will, when completed, give a saving of £3 per week.

Say that this work may be executed at the soonest in 2 months, or that it may be spread over 5 months. At the end of 5 months, the gain of the former method, on the basis of the same rate per fathom in both cases, would be as follows:—

			£	s.	d.
Three months at £3 per week, say	...	...	36	0	0
Interest, say	...	...	1	12	0
Total	...	...	37	12	0

In this case, therefore, £237 12s. spent in 2 months is no more, as regards results, than £200 spent in 5 months, and it would be worth while to pay a considerably increased rate to get the work quickly completed.

The question of when repairs should be executed is a matter for careful consideration. "A stitch in time saves nine" in many cases, but at the same time, while plant should be kept in good order, it is difficult to keep everything in perfect condition, and it may be better at times to have a little waste than to have constant expenditure.

It is unnecessary further to multiply illustrations. Enough has been said to emphasize the point that, in dealing with all details of colliery management, the same principle should rule. The general attitude of mind ought to be that all new developments and arrangements and operations of all kinds should be subjected to the test of figures—should be looked at from all points of view with minds trained to find the possible difficulties and advantages in connexion with the various alternatives which suggest themselves.

I am perfectly aware that, in making this statement, I am not adding anything that is new to the knowledge of the members, but those who most fully realize the truth of what it has been my endeavour to illustrate will be the most ready to admit the difficulty of applying the principle, and that on account of the difficulty it is perhaps excusable to spend some time in emphasizing its importance.

We have had few papers read before our Institute dealing specially with the minute details of colliery management, and yet no more useful paper could be given than one containing an account for the year for a going colliery of the details and cost of upkeep of different kinds of machinery, haulage-roads, hutches, or an account of the cost of drawing from faces to haulages and by haulages themselves. Such statistics would be exceedingly valuable.

It is a matter of regret that during the past year we have had so few papers. Those read to us have been good, interesting papers; but there have not been as many as we should have to make the meetings as interesting as they ought to be. Members should remember that simple records of experience are often most valuable; they should be ready to give such contributions, and not wait till they have something of outstanding interest to bring before the Institute. Descriptions of small improvements in mechanism, of designs for labour-saving appliances, of modifications in workings, of different forms of propping, and of arrangements for pit-heads and pit-bottoms—all are good subjects for papers. Further improvements in mining are by no means impossible, and if we consider carefully we shall find that many economies might be devised. For

example, it would be of great advantage if the shifting of waggons were under the control of the trimmers. If there were some mechanical appliance by which the shifting could be managed, so that the waggon could be advanced a few feet at a time by the trimmer without descending to the rail-level, some labour would be saved, and the coal could be loaded with a good deal less breakage. It should be comparatively easy to design some method for attaining this end.

Perhaps improvements would come more quickly if we were continually seeking them, and if we were not so much inclined to look upon the latest arrangement as the best possible, as we are so apt to do. We should be always alive to the fact that just as improvements have taken place in the past, so they will in the future.

In considering the question of the subjects for papers, let us always remember that a very short paper may bring out a most valuable discussion, as, for example, the paper read at the Cardiff meeting last year by Mr. W. Galloway on the subject of "Secondary Haulage."* This paper was only $5\frac{1}{2}$ pages in length, and yet the discussion which followed filled $16\frac{1}{2}$ pages of the *Transactions*.

It is to be hoped that nothing will be wanting this session to make the meetings of the Institute interesting.

DISCUSSION ON MR. PRENTICE'S PAPER ON "THE MINERAL SEAMS OF NEW MONKLAND."†

The PRESIDENT declared the discussion closed, and proposed a vote of thanks to Mr. Prentice for his paper, which was agreed to.

Mr. WALTER H. MUNGALL read the following paper on "Screening-plant at Mossbeath Colliery":—

* *Trans. Fed. Inst.*, vol. xii., page 257.

† *Ibid.*, pages 435 and 619.

SCREENING-PLANT AT MOSSBEATH COLLIERY.

BY WALTER H. MUNGALL.

Mossbeath colliery is one of the collieries of the Fife Coal Company, Limited, and is situated near Cowdenbeath, close to the Edinburgh and Perth section of the North British railway. There are two winding-shafts, the produce from which is dealt with at one common screening-plant. The winding-engines at both pits have two horizontal cylinders, each 21 inches in diameter and $4\frac{1}{2}$ feet stroke. Steam at a pressure of 100 lbs. per square inch is supplied by 5 Lancashire boilers, each 30 feet long by $7\frac{1}{2}$ feet in diameter.

The screening-plant, which has been in operation for about a year, consists of a series of picking-tables with fixed bar-screens, and the requisite subsidiary conveyors and elevators (Figs. 1, 2, and 3, Plate XII.). The tubs from each shaft are weighed on the turntable steelyard *S*, whence they pass to the various tippers. The rails from No. 2 shaft to the steelyard are laid with an inclination towards the steelyard and again the rails from the steelyard to Nos. 2 and 3 tippers have a gradient towards the tippers, and by this means there is as far as possible a saving of manual labour.

The tippers are of the revolving geared type, driven by friction-clutches, and are fitted with an automatic knock-off, by which arrangement the tippler comes to rest after having made one complete revolution. After being emptied, the tub is pushed out of the tippler by the next succeeding full one and it gravitates to the self-acting steam-hoist, where each tub is lifted to such a height that it again gravitates to the back of the shafts. By these appliances, the tubs make the complete circuit from the shaft to the tippers and again back to the shaft almost entirely automatically.

Just outside the hoist, and actuated by the cage, is a hutch-regulator. As the cage descends, one hutch is released and, running by gravity into the cage, comes in contact with the kicker, *k* (Figs. 4 and 5, Plate XII.), which is keyed on the shaft, *s*. By means of the wyper, *w*, and connecting-rod, *r*, motion is communicated through the wyper-shaft, *a*, and wyper, *b*, to the bell crank, *c*, which in turn actuates the valve-spindle, *v*.

When the cage ascends so that the hutch is raised above the guide-bar, *g*, the hutch immediately, owing to the inclination of the cage, runs off, and the axle coming into contact with the lever, *l*, depresses it, and reverses the motions communicating with the valve. As the steam exhausts, the cage again descends, releasing the next hutch from the regulator, and the same operation is repeated. The steam-cylinder is 6 inches in diameter; the inclination of the cage is 1 in 18, and the inclination of the rails as the hutch leaves the cage is 1 in 18 for the first 6 feet and after that 1 in 48 to the back of No. 2 shaft.

Immediately after leaving the cage, the hutch passes over a mechanical greaser. The inclination from the hoist to the back of No. 2 shaft being such as to cause the hutchs to move by gravitation all the way, it is obvious that the gradient to No. 1 shaft must be much too steep, and some means of braking the hutchs had to be adopted. Spring-boards under the hutchs were first introduced, but these were troublesome and were discarded in favour of the present arrangement, a cross-section of which is shown in Fig. 6 (Plate XII.). *b* is a wooden batten faced with iron, to each end of which a chain is fastened. This chain passes over a small pulley, and is attached to the weight *w*. When the hutch passes down this steep gradient, these brake-beams press against the inside of the wheels and act most effectually, the amount of pressure being regulated by the weights *w*.

When the coal is emptied from the hutch by the tippler, it descends by a steel shoot to the distributing-band, whence it passes over a fixed bar-screen—the bars of which are $1\frac{1}{2}$ inches apart—on to a picking-band (Figs. 2 and 3, Plate XII.). Nos. 1 and 2 picking-bands are of the German type, 4 feet wide, and composed, not of plates, but of round bars running across the table, the bars being $\frac{3}{4}$ inch in diameter, and the spaces between them $\frac{5}{8}$ inch. Dust or small, made in picking the coal, passes through these spaces and falls on to a steel plate underneath the returning part of the picking-band. At intervals along the band are cross angle-irons which act as scrapers on the under or return side of the band, and convey what may have passed between the bars back to the dross-conveyor. These two picking-bands are 18 feet long, from centre to centre, and are hinged near the middle so that the front portion of the band can be lowered to the bottom of the waggon and raised gradually as the waggon fills, thus reducing the fall and consequent breakage of the coal to a minimum. The end of the table is raised and lowered by a right and left-handed friction-clutch connecting with the necessary gearing overhead, and is balanced by weights hung clear of the lines of railways.

No. 3 picking-band is of the ordinary plate type, and delivers the coal on to a jiggling-screen, the perforations in which are of such diameters as may be required. The outer end of this jiggling-screen is fitted with an adjustable shoot that can be raised or lowered at will by means of a worm-screw, worked by hand. The coal that passes through the perforations of this jiggling-screen is carried by a cross German band, 3 feet wide, and discharged into waggons on No. 4 road.

All the dross that passes through the fixed bar-screens is carried by a flight-conveyor, running across the lines of railway and discharged into waggons, or the dross pit, as desired. Thence it is raised by an elevator, and delivered on to a compound jiggling-screen. The eccentrics actuating this screen are set in pairs, diametrically opposite each other, on the driving shaft; thus the forward motion of the one screen is synchronous with the backward motion of the other, and the shock is reduced to a minimum—the shock effect of the one screen being counterbalanced by that of the other. By this screen, the small coal is separated into three sizes—large nuts, passing over the upper screen; single nuts, passing through the upper and over the under screen; and duff, passing through both screens. The nuts are delivered by the jigger on to a German picking-band, where any stones are picked out. The single nuts pass direct to waggons, while the duff is delivered on an inclined flight-conveyor 128 feet long, whence it passes to another similar conveyor running along the front of the boilers and at right angles to the first conveyor. In this second duff-conveyor are several sluices, one opposite each boiler, so that the duff can be supplied to the boilers as required. Provision is also made, by a sluice in the bottom of the first conveyor, for loading duff into waggons when required (Figs. 1 and 2, Plate XII.).

One noteworthy feature of this plant is the design and construction of the screening substructure, which is composed of old rails weighing 60 pounds per yard, and is so designed that there are no columns between the four lines of railway. This arrangement eliminates all risk of accidents occurring through workmen being crushed between wagons and intermediate supports. A braced framework along each side (Fig 8, Plate XII.) supports the ends of cross-trussed beams, from which is hung a horizontal network of rails; the longitudinal and transverse members being braced together by diagonal bracing (Fig. 7, Plate XII.). The part shown is the closing piece of the structure, and it may be mentioned that the several bolt-holes in it were bored, not from template or from measurements of the place where the bracing was to go in, but from the measurements on the working plans; and although these holes

were bored only $\frac{1}{16}$ inch in diameter greater than the bolts that were to go in them, not a single bolt required more than a hand hammer to send it home. On this horizontal network, above referred to, the screening-plant is built, and the design and construction are such that the whole structure is exceedingly rigid.

Mr. FAULDS (Calderbank) said that Mr. Mungall's tipplers were similar to those in use at the majority of collieries, while those described in Mr. Hastie's paper were placed at an angle to the roads.

The PRESIDENT said that Mr. Mungall described a self-acting hoist, which, he thought, in Scotland was an unusual thing, although it was not so in England.

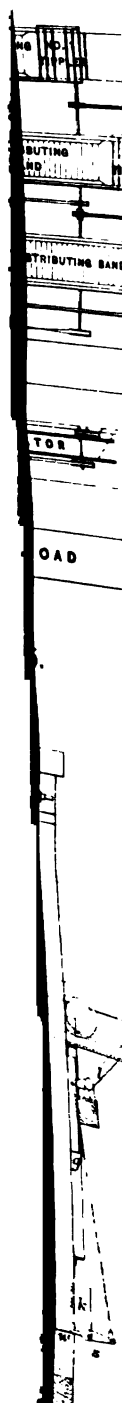
Mr. MUNGALL said that the principal reason for adopting the self-acting hoist was that it was recommended as being better than the ordinary gripper. It was working very satisfactorily. Of course, the output from the pit was not so large as it would be ultimately.

Mr. FAULDS said he understood that, with the creeper in use, there was a great amount of shock at the change from the descending to the ascending gradient.

The PRESIDENT remarked that Mr. Mungall used bar instead of jiggings-screens. He had heard a discussion lately on the comparative merits of the two systems, and one engineer, who had made experiments, contended that there was more breakage with jiggings-screens than with bar-screens.

Mr. MUNGALL said he did not know that he could give any statistics as to the comparative merits of the two screens in the matter of breakage. Bar-screens were adopted so as to conform to their arrangements with the landlord.

The further discussion was adjourned.



MIDLAND INSTITUTE OF MINING, CIVIL, AND
MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD IN THE HARVEY INSTITUTE, BARNSELY, MARCH 27TH, 1897.

MR. G. B. WALKER, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected, having been previously nominated :—

MEMBERS—

Mr. WILLIAM MACKENZIE REYNOLDS, Mining Engineer, Dukinfield Coal and Cannel Company, Dukinfield.

Mr. WILLIAM J. WATERMAN, Mining Engineer, Vancouver, British Columbia.

STUDENT—

Mr. HERBERT PRKIN, Mining Student, Typoville, Alexandra Road, Leeds.

Mr. H. ST. JOHN DURNFORD read the following paper on "The Use of Electricity at Ackton Hall Colliery," by Mr. H. St. John Durnford and Mr. Roslyn Holiday :—

THE USE OF ELECTRICITY AT ACKTON HALL COLLIERY.

BY H. ST. JOHN DURNFORD AND ROSLYN HOLIDAY.

The uses to which electricity may be put at a large colliery are manifold, and at Ackton Hall colliery practical tests have been rigidly applied to several purposes, an account of which may not be without interest to members of the Institute.

Soon after the present proprietor became possessed of the colliery, electricity was brought into use for the purpose of lighting, and from 1891 up to the present time its use has been constantly increased, till now, besides providing all the illumination for the pit-bottom and surface, there are upwards of 12 motors running in various parts of the works. The writers will describe in the present paper some of these motors and the work which they perform, together with the various dynamos employed for generating the necessary power. They also hope to show that economical results have been obtained by the substitution of electricity for steam in many instances.

The first plant erected was used for lighting only, and consisted of an ordinary horizontal engine with two cylinders 12 inches in diameter, working a dynamo, capable of giving out 220 ampères at 110 volts. The necessities of space in the engine-room very shortly caused a remodelling of the plant, and two compound engines were erected.

The power for lighting the works and working the various motors is all produced at the central station, built in close proximity to the boilers which also provide steam for the three winding-engines at work. Two compound engines are in use, each with cylinders $8\frac{1}{2}$ inches and 14 inches in diameter respectively, and 11 inches stroke, which work together or independently on to one shaft by means of friction-gear, and drive the Castle dynamos, one at 200 volts pressure, and the other two at 110 volts each, being used chiefly for lighting. The 200 volts dynamo has an output of 220 ampères, and the two 110 volts dynamos also an output of 220 ampères each. A small high-speed Bumsted-and-Chandler engine and Castle dynamo, used chiefly for lighting, is capable of giving out 100 ampères at 110 volts. The plant contained in this room has done a very

large amount of work, and the engines have given satisfaction ; but, owing to the fact that a speed of 250 revolutions per minute has to be maintained, considerable strain is put on the foundation-bolts, etc., and it has been found necessary to insert heavier foundations than were at first deemed necessary.

The 200 volts dynamo was put down in the first instance to generate electricity for working a pump by means of a 25 horse-power motor, placed at the bottom of the water-pit 210 feet below the surface. It has worked without any hitch for the last three years, being stopped and started from the surface, and only requiring attention once in 12 hours. The quantity of water which this motor will lift is 9,000 gallons per hour, running at a speed of 50 revolutions per minute. It may be remarked that the water-supply of the colliery up to the recent dry summer, when the increased output of the colliery necessitated additional arrangements, was entirely dependent upon this pump. The old-steam pump, which was formerly used for lifting the water, has been taken out. At the same time as this pump was set to work, a smaller three-throw pump was obtained to deal with a feeder of water which was troublesome in the sump of the winding-pit. This pump, worked by a 12 horse-power motor, 1,000 feet below the surface, forces the water up the pit in one lift, and works about 10 hours a day.

About three years ago it became necessary to erect a new joiners' shop in the place of one which was burnt down during the riots which took place during the coal strike of 1893, and it was decided to apply a motor to work a circular saw and other machinery in the building which had been put up at some little distance from the boilers. The writers would draw attention to the fact that at all modern collieries a steam-pressure of 100 to 120 lbs. on the square inch is maintained ; and it will be found that to keep a range of pipes with steam under this pressure in proper repair for any distance without considerable waste is troublesome, especially as the steam-pressure is liable to fluctuation, and consequent contraction of the pipes results. A 25 horse-power motor was erected in September, 1894, and with the exception of slight trouble with the original armature, which was changed by the makers soon after it was started, the motor has cost nothing in maintenance or repairs, beyond the usual cost for oiling and cleaning. The total cost of this plant, including motor-foundations, 660 feet of cable, fixing of motor, switches, etc., was £117. This price includes moreover half the cost of a spare armature, which will also fit the motor intended to drive the machines in the mechanics' shop.

The 25 horse-power motors are all continuous-current machines, working at 200 volts pressure and a speed of 1,500 revolutions per minute, each motor being supplied with an ammeter switch and cut-outs, the power from the dynamos being carried on cables 19'16, and 600 megohms insulation. The drop in pressure on the transmission of electricity from the dynamo to the motor working the saw-mill is found to be 7 volts when working at full load. Very soon after the saw-mill had been set to work, a similar motor was erected in the fitting-shop for working the lathes and fan for the blacksmiths' fires. Both of these motors are securely boxed in wooden cupboards to prevent filings and nails from being attracted. A similar type of motor of 6 horse-power was also added to the plant to work the hay-chopper and corn-grinding machinery attached to the stables, at a distance of about 900 feet from the electric engine-house and dynamo. The latter motor is run from the 110 volts circuit and uses about 15 ampères to do the work that is necessary. The saw-mill and mechanics' shop motors each take an average of 22 ampères. One point in favour of motor-work which can be noticed, is the fact that they take a very small amount of power to drive them when running light, the saw-mill in particular using 10 ampères when simply running the saw round, and as much as 100 and more when a heavy cut is in progress.

A 12 horse-power motor, working a Gwynne centrifugal pump, put down at the water-reservoir, about 1,500 feet from the works, lifts 12,000 gallons per hour a height of about 70 feet into a tank, from which it is supplied to the boilers: the power for working this motor being carried from the central station by two bare copper cables 19/12.

When the question of washing coal or slack first came up for consideration, and on its being decided to erect a large Lührig coal-washer, capable of dealing with 500 tons a day, the problem was how best to drive the machinery, and the writers, having at that time obtained nothing but satisfactory results from the use of electricity as a motive power, considered it advisable to go into the question of applying it to the washery. Owing to the site selected for the plant being at some distance from the boilers, either a new set of boilers with chimney would have to be erected, or the steam would have to be carried to the building by a long range of pipes.

Adjoining the engine-house described above, another room has been built, with direct communication with the old room, containing two Parsons 200 electric horse-power steam turbines and dynamos, working at 500 volts pressure, and running at 3,000 revolutions per minute. These

machines are now well known, and have proved successful under the conditions under which they are working at Ackton Hall colliery. Figs. 1 and 2 (Plate XIII.) give a general idea of the machines, which are constructed so as to give out their maximum load at a steam-pressure of 80 lbs. to the square inch, when running at the above-mentioned speed. It is difficult to see how these turbines, or rotary engines as they may be called, can get out of order. Trifling difficulties have been met with in connexion with the armatures, but these have now been overcome, and for the amount expended they seem to be efficient machines. The absence of the usual heavy foundations, in the writers' opinion, is a great point in their favour. The steam enters the turbine from a pipe 3 inches in diameter, and is admitted in periodic blasts, 1 in every 15 revolutions of the turbine. The steam, after its passage through the turbine, passes through blades, and as it expands it comes in contact with blades of larger diameter, and finally exhausts into a pipe 12 inches in diameter. The makers guarantee a water-consumption per electrical horse-power per hour of not more than 39 lbs.

The cost of a Parsons 200 electric horse-power turbine and dynamo may be taken as about equal to the cost of a first-class steam-engine of equal power, without a dynamo. It has been found necessary, in order to maintain these machines at the requisite speed without undue heating of the bearings, to pass the oil used for lubricating through an oil-cooler, which is simply a spiral pipe enclosed in a cast-iron casing through which passes a constant flow of cold water. The complete plant measures 17 feet long by 3 feet wide, and no foundations are needed, the machines simply resting on indiarubber mats. The turbines are electrically governed, and a variation in voltage of not more than 5 per cent. ensues when the whole load is thrown on or off.

The power is carried to the coal-washery by three pairs of 19/14 bare copper wire, this being cheaper and safer than having one pair of large cables. It might be mentioned that the builders of the washing-machinery were doubtful as to the actual amount of power required for working the machinery and keeping the water circulating, but provision was made for sending 240 horse-power into the building in case of necessity. It has since been proved that this was an excessive estimate of what was actually required, but the fault is on the right side, the actual power required being 180 electric horse-power. The 240 horse-power which was considered necessary to work the washery is distributed over three 80 horse-power motors (Figs. 3 and 4, Plate XIII.), two of which work the elevator, washing-tanks, revolving screen, dirt-scrappers, etc.; the

other drives the disintegrator, used for crushing nuts for mixing with the coking coal when a superior quality of coke is required.

An absolutely uniform speed is maintained by the use of these motors, and many members will know how essential this is in machinery of this class, if good results are to be obtained. It is necessary at times during the cleaning and letting off of the water from the mud-tanks, for the main shaft of the machinery to be run at a slower speed than usual. The normal speed of the main shaft in the building is 60 revolutions per minute, the speed of the motors being 620 revolutions per minute. The speed of the main shaft can be reduced to 2 revolutions per minute by means of two special switches, one of which puts the armatures of the two motors into series bringing the speed down to half, and the other puts the windings of the magnets into parallel, thus reducing the speed down to nearly one-fourth, and then, by using the starting resistances, the speed can be still further reduced.

The question of underground haulage was before the writers' minds during the time when the motors were being got ready for the washers, and it was decided to apply electricity for underground haulage in all the pits as occasion arose. Three separate plants, each driven by a 40 horse-power motor (Figs. 5 and 6, Plate XIII.), have already been got to work, two similar in character, working endless-ropes, and one smaller plant which is engaged in hauling material up some stone-drifts.

The Warren House coal-seam lies at a depth of 1,000 feet from the surface, and as the workings had extended to a considerable distance from the shaft, it was decided to put haulage-machinery into that pit without delay. The endless-rope system has been adopted, the rope working at the top of the tubs with ordinary chain-attachments. Owing to the difficult character of the roof of the seam, considerable expense and delay were incurred in widening the roads, but now that this has been satisfactorily accomplished, no difficulties are found. The motors are run off the 500 volts circuit, having a speed of 550 revolutions per minute, geared down first by leather-belting and then by spur-gearing, and the rope travels at a speed of 3 miles an hour. The output of the pit is 1,100 tons a day, three-fourths of the coal being drawn on the endless-rope road. The seam is flat, and at the present time the actual power required is only about 20 horse-power, or less than half of the capacity of the motor. The cables for carrying the power to these motors are 19/16, 300 megohms insulation-resistance, and like others in underground use at the colliery, are suspended from the top of the pit without any intermediate support.

A patent oil-insulator consisting of an annular cast-iron vessel with a lug on each side, by means of which it can be suspended, is used (Fig. 7, Plate XIII.). At the bottom of the annular space is a thick ring of indiarubber on which rests the support which carries the weight of the cable, the remainder of the space is filled with creosote oil, and the cable is held by an ordinary wrought-iron rope clamp. The cables suspended in this way have never caused the slightest trouble, there being nothing for falling coal, etc., to catch. Insulation-tests are made weekly of all the circuits, and the shaft-cables always afford the best results. The cost of putting in one of these cables in connexion with the Haigh Moor haulage was found to be as follows:—1,100 yards, 19/16, 1,000 megohms cable, £73 6s.; two oil-insulators, 12s.; 4 workmen, each $\frac{1}{2}$ day, 10s. 6d.; winding engine-man $\frac{1}{2}$ day, 3s. 4d.; total, £74 11s. No difficulty has been experienced by having these cables hung in the manner described, and in the writers' opinion for depths of 2,000 feet it is quite safe. The cables are made to sustain their own weight, but by having them armoured, as in the case of one pair in use in the Haigh Moor shaft, an ample margin of safety is assured. The motor down the Haigh Moor shaft is at present working two endless-ropes, one about 1,500 feet, and the other one 3,000 feet long, and the power used has been found to be about one-third of what the motor is capable of producing.

Figs. 8 and 9 (Plate XIII.) show a small haulage-plant which has been just set to work for hauling material up the stone-drifts already alluded to, and has been found to be extremely convenient for the purpose. The 25 horse-power motor sets in motion two drums, each 3 feet in diameter and 12 inches wide, and it is geared down by spur-gearing to travel at a speed of 5 miles an hour when the motor is running at full speed. The cables for conveying the power to this motor are a continuation of the cables used for driving the motor in connexion with the Haigh Moor haulage. They are 19/16, and 300 megohms insulation, carried along the main intake airway to a point about 1,800 feet from the shaft, where the machinery is fixed. This machine will be most useful after its present occupation has ceased, as it can be taken to pieces in a couple of days and moved to any other part of the underground workings of the colliery where a similar drift may have to be driven.

An 8 horse-power motor is working a three-throw pump, at a distance of 2 miles from the colliery, which is used in dry times to pump water for colliery purposes. This motor can be stopped or started without any difficulty from the engine-room, and an ingenious method

has been adopted to prevent (a) its running away, in case the belt connecting the motor to the pump slips off or breaks, and (b) damage which would arise from the pump or motor-bearings getting hot. For these purposes, a starting-switch is constructed, so that when the normal current is passing, a small trigger holds the switch in position; and when the current falls below 5 or rises above 18 ampères, the switch is released and the pump thereby stopped automatically.

The Haigh Moor screening-plant is driven by means of a 40 horse-power motor, similar to the two motors driving the Warren House and Haigh Moor haulages. It is of the four-pole type, with self-oiling bearings, running at 550 revolutions per minute. It is working at full load, and works very satisfactorily.

There is a hoist which lifts the tubs of coking coal to the level of the top of the coke-ovens, a height of 20 feet. The tubs contain 15 cwts. each. A 12 horse-power motor is used to work this hoist; it has been running for 8 months, and during that time it has had no attention whatever, and has not used one pint of oil, the bearings being self-lubricating, and using the oil over and over again.

A small motor is also used to drive a lamp-cleaning machine.

The total load on the central station is often as much as 320 horse-power, and in less than a minute it may drop to 50 horse-power.

The writers are in somewhat of a difficulty in speaking definitely as to the question of economical results by adopting so largely the use of electricity for power purposes, as all the steam used at the colliery is supplied from the same main steam-pipe, and by the same range of boilers as those that supply the winding-engines, etc.; but inasmuch as the colliery consumption of coal is not excessive, considering the amount of work done and the depth of the shafts, it is believed that the use of so much electricity is not extravagant. Most certainly, the power sent to drive the washery is maintained at a minimum cost. There are no charges for repairs to leaking pipes, no repairs to engines, no packing of glands, and less attention than would be needed by an engine of the same power as the two 80 horse-power motors. The only item of expense connected with these motors since they commenced work in May, 1896, has been once re-turning of the commutators. The writers believe that the use of electricity at Ackton Hall collieries has resulted in great saving of expense and increased efficiency. In the use of electricity for power purposes, one particular feature of motors should be borne in mind, namely, that whatever load is put on to them is taken up;

FIG. 7.

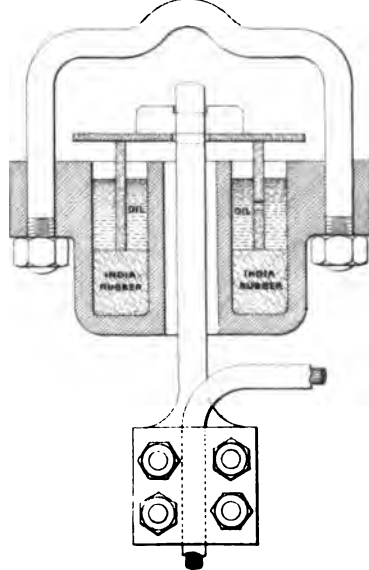
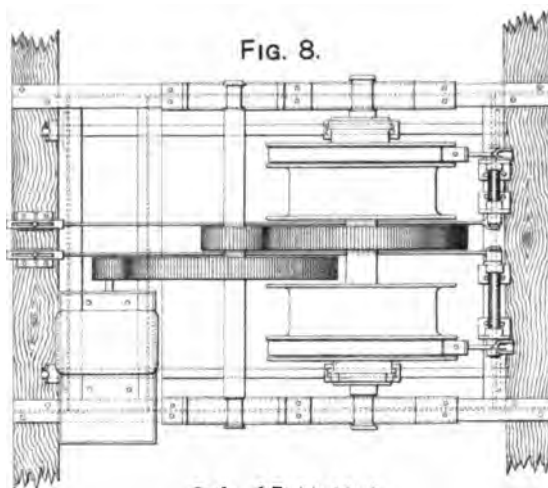
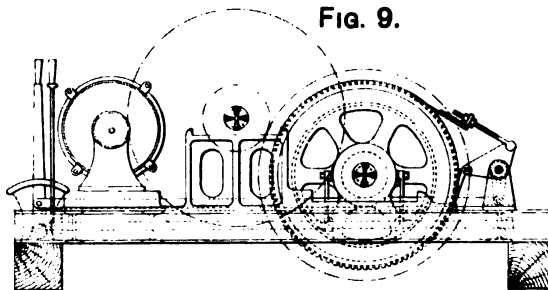


FIG. 8.



Scale, 4 Feet to 1 inch.

FIG. 9.



whereas, an engine in similar circumstances would be slowed down ; so that it is most important to have motors built above the work which they are intended to perform. To this fact, as well as to having everything of the best construction, is attributed in a great measure the success of the application of electricity at Ackton Hall collieries:

The PRESIDENT asked—with regard to the breaking strain of the cable—at what strain the copper in the cable suspended down the shaft would break. He understood that the cable was not supported at any intermediate point, and that it was about 1,000 feet in length.

Mr. E. BROWN (St. John's collieries) remarked that the consumption of 39 lbs. of water per horse-power per hour by the Parsons turbine seemed extravagant, as an ordinary compound engine only consumed about 14 lbs. of water per horse-power per hour. It would be interesting to isolate a boiler and ascertain exactly the water-consumption per horse-power. With reference to hanging cables in the shaft, he understood that the cables were armoured, so that probably the armour would be capable of carrying the whole cable without any strain on the copper wires. At St. John's collieries the cables in the shafts were lead-covered, and pieces of coal falling from the tubs punctured the lead and great leakage ensued, and for further protection the cables were now enclosed in wooden boxes, nailed to the stays : at intervals of about 150 feet, a piece is scooped out of the box about the size of a hen's egg, and at that point a swelling is worked on the cable by tape and varnish to fit the scooped-out portion in the box, and thus the cables are supported at intervals of 150 feet by an arrangement which acts satisfactorily. When a small plant had to be erected at a distance of 2 miles from the colliery there was no doubt that electrical transmission was the most suitable power for such cases. Within a range of 1,000 feet, he should doubt the economy of erecting electric plant as opposed to a steam plant, but electricity had the advantage when the plant was standing, as the losses were *nil* ; whilst in a steam-pipe the condensation would be a serious loss of power, because the steam could not be shut out of the pipes. For a plant run at intervals, an electrical plant would compare favourably with a steam plant.

Mr. A. A. ATKINSON (Barrow collieries) asked whether any arrangement had been made at the hauling-engines to enclose the sparks which might be made at the commutator.

Mr. T. B. A. CLARKE (Lidgett colliery) said that hanging the cable down the shaft seemed to have given no bad results, but it was doubtful whether in time the cable might not suffer serious damage, not so much from the fact that the cable might not be able to bear the strain, but from the fact that the cable was built up of at least three different substances which, under tension, might stretch unequally. The cable might be extended, and, rubbing on the inner surface of the copper, waste away the insulating capacity of the cable. Steam-turbines no doubt gave excellent results, but whether they could meet sudden demands for increased power suddenly thrown on them had not been proved. He would like to know how long the turbine had been in use, and what was the cost of maintenance as compared with an ordinary compound engine. The coal-washing plant had been erected within a distance of 900 feet from the generating-station, and if electricity could economically displace steam-power for a plant put down within that distance it could displace it almost anywhere. Could the writers give information as to the costs: first, in driving the plant electrically, and, second, in driving by steam-power, and also the costs of maintenance in each case?

Mr. HOLIDAY (Ackton Hall colliery), replying, said that the breaking-strain of the cable was 30 cwts. and its weight was about 4 cwts. By hanging the cables in the shaft from the surface, and using no insulators, there could be no leakage. The cables hung 5 or 6 inches from the side of the shaft and 1 foot from each other. Some tubs had fallen down the shaft, and the cables were grazed, but not damaged. Two or three different substances were used in the cable, which would stretch unequally; but in a suspended cable this did not make the slightest difference, and a bare cable would do just as well. Insulated cables were used at Ackton Hall collieries to prevent the shaft men from getting a shock. The turbines were guaranteed to consume not more than 39 lbs. of water per electrical horse-power per hour, and the consumption per indicated horse-power would be much less. The makers guaranteed, if the exhaust steam was condensed, a consumption of 17 lbs. per electrical horse-power, or about 14 lbs. per indicated horse-power. One pair of the shaft-cables was armoured; but, if the armour came in contact with anything, it created a tendency to leak along the whole length of the cable, as the armour was in connexion with the insulation, whereas, if the cable was

unarmoured, there was no tendency to leak. There was no protection against sparking of the small haulage-motor, which was placed in the main intake airway, and it was not necessary to incur the expense of enclosing the motor. The turbine-governors worked efficiently, under loads varying from 280 to 50 horse-power, within less than 1 minute. In working the rope-haulage, it was stopped and started all day long, and no variation of speed of the turbine took place. All the parts being rotary, and none of them reciprocating, the load was only like a brake upon them ; whereas in engines with reciprocating parts there was a tremendous strain thrown on the cranks and motion-work of the engine, so that the turbine seemed more suitable than any other engine for working with varying loads. The cost of the central station in wages was £3 4s. a week, and stores £2 a week. Repairs and maintenance were very low indeed, though he could not give the exact figures.

The PRESIDENT moved a vote of thanks to the authors for their paper.

Mr. T. B. A. CLARKE seconded the motion, which was carried unanimously.

BARNSELEY MINING SCHOOL.

The PRESIDENT moved "That the Council and Members of the Midland Institute of Mining, Civil, and Mechanical Engineers consider that progress is being made in connexion with the Course of Mining Lectures at Barnsley, and that it would be unfortunate if the County Council discontinued the grant now that the classes appear to be more largely taken advantage of."

Mr. A. M. CHAMBERS seconded the motion, which was agreed to.

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THE FEDERATED INSTITUTION OF MINING ENGINEERS.

SUBJECTS FOR PAPERS:

The Council of The Federated Institution of Mining Engineers invite original communications on the subjects in the following list, together with other questions of interest to mining and metallurgical engineers.

For selected papers, the Council may award prizes. In making awards, no distinction is made between communications received from members of the Institution or others.

Assaying.

Blowing out of coal and minerals *in situ*.

Boiler explosions.

Bore-holes and prospecting.

Boring against water and gases.

Brickmaking by machinery.

Canals, inland navigation, and the canalization of rivers.

Coal-getting by machinery.

Coke manufacture.

Colliery explosions.

Colliery leases, and limited liability companies.

Compressed air as a motive-power.

Consumption of steam and water in engines.

Descriptions of coal-fields.

Diamond-mining.

Distillation of oil-shales.

Drift and placer-mining.

Duration of coal-fields of the world.

Electric mining lamps.

Electricity and its applications in mines.

Electro-metallurgy of copper.

Engine-counters and speed-recorders.

Explosions in mines.

Explosives used in mines.

Faults and veins.

Fuels and fluxes.

Gas producers, and gaseous fuel and illuminants.

Gas, oil, and petroleum engines.

Geology and mineralogy.

Haulage in mines.

Industrial assurance.

Inspection of mines.

Laws of mining and other concessions.

Lead-smelting.

Lubrication of trams and tubs.

Maintenance of canals in mining districts.

Manufacture of fuel-briquettes.

Mechanical preparation of ores and minerals.

Mechanical ventilation of mines, and efficiency of the various classes of ventilators.

Metallurgy of gold, silver, iron, copper, lead, etc.

Mineral resources of colonies.

Mining and uses of asbestos, bauxite, etc.

Occurrence of mineral ores, etc.

Ore-sampling machines.

Petroleum-deposits.

Prevention of over-winding.

Pumping machinery.

Pyrometers and their application.

Quarries and methods of quarrying.

Rectification of mineral oils.

Safety-lamps.

Salt-mining, etc.

Screening, sorting, and cleaning of coal.

Shipping and discharge of coal-cargoes.

Sinking, coffering, and tubbing of shafts.

Smelting.

Spontaneous ignition of coal and coal-seams.

Submarine coal-mining.

Sulphur-mining.

Surface-arrangements of mines.

Surveying.

Tin-mining.

Tunnelling, methods and appliances.

Utilization of dust and refuse coal.

Utilization of sulphureous gases resulting from metallurgical processes.

Ventilation of coal-cargoes.

Ventilation of mines.

Water as a motive-power in mines.

Watering coal-dust.

Water-incrustations in boilers, pumps, etc.

Winding arrangements at mines.

Winning and working of mines at great depths.

MEDALS AND OTHER AWARDS.

SESSION 1889-90.

"The Economical Working of Steam Boilers at Collieries." By Messrs. William Armstrong, Junior, and W. J. Bird.

"Improved Coal-screening and Cleaning." By Messrs. T. E. Forster and H. Ayton.

"Winding, Banking-out, and Screening Plant at East Hetton Colliery." By Mr. Simon Tate.

"Coal-getting by Machinery." By Mr. G. Blake Walker.

SESSION 1890-91.

"Experiments on Explosives used in Mines." By Mr. M. Walton Brown.

"Experiments with Carbonite." By Messrs. M. Walton Brown and William Foggin.

"Notes on the Coal-fields of New South Wales." By Mr. G. Blake Walker.

SESSION 1891-92.

President's Prize (Mr. George Lewis).

Mining in New Zealand." By Mr. G. J. Binna.

unarmoured, there was no tendency to leak. There was no protection against sparking of the small haulage-motor, which was placed in the main intake airway, and it was not necessary to incur the expense of enclosing the motor. The turbine-governors worked efficiently, under loads varying from 280 to 50 horse-power, within less than 1 minute. In working the rope-haulage, it was stopped and started all day long, and no variation of speed of the turbine took place. All the parts being rotary, and none of them reciprocating, the load was only like a brake upon them ; whereas in engines with reciprocating parts there was a tremendous strain thrown on the cranks and motion-work of the engine, so that the turbine seemed more suitable than any other engine for working with varying loads. The cost of the central station in wages was £3 4s. a week, and stores £2 a week. Repairs and maintenance were very low indeed, though he could not give the exact figures.

The PRESIDENT moved a vote of thanks to the authors for their paper.

Mr. T. B. A. CLARKE seconded the motion, which was carried unanimously.

BARNSELY MINING SCHOOL.

The PRESIDENT moved "That the Council and Members of the Midland Institute of Mining, Civil, and Mechanical Engineers consider that progress is being made in connexion with the Course of Mining Lectures at Barnsley, and that it would be unfortunate if the County Council discontinued the grant now that the classes appear to be more largely taken advantage of."

Mr. A. M. CHAMBERS seconded the motion, which was agreed to.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD IN THE ROOMS OF THE ROYAL SCOTTISH SOCIETY OF ARTS, EDINBURGH,
JUNE 12TH, 1897.

MR. GEORGE A. MITCHELL, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected:—

MEMBERS—

Mr. ROBERT GILCHRIST, Greenfield Colliery, Shettleston.
Mr. EDWARD GREGORY, Wellington Colliery, Whitehaven.
Mr. ROBERT JAMES, New Alburnia Mine, Thames, Auckland, New Zealand.
Mr. C. T. KEARTON, Montreal Mines, Cleator Moor.
Mr. HUGH MCPHEE, 2, Regent Park Terrace, Strathbungo, Glasgow.
Mr. THOMAS J. NIMMO, 5, West Regent Street, Glasgow.

ASSOCIATE MEMBERS—

Mr. ROBERT COWIE, Bathville Engineering Works, Armadale.
Mr. FRANCIS MCKEAN, 19, Waterloo Street, Glasgow.

DISCUSSION ON MR. J. HASTIE'S PAPER ON "SINKING, SURFACE-FITTINGS, AND COAL-CLEANING PLANT AT WHISTLEBERRY COLLIERY,"* AND MR. W. H. MUN- GALL'S PAPER ON "SCREENING-PLANT AT MOSS- BEATH COLLIERY."†

Mr. A. FAULDS (Calderbank) said that in his experience there was less oncost with the creeper than with the hoist, and it was safer.

The PRESIDENT remarked that while fixed and jigging-screens might produce the same amount of dross, it was possible, as some contended, that jigging-screens shook the coal more, and that there was more breakage after the coal left the colliery.

* *Trans. Fed. Inst.*, vol. xii., page 622.

† *Ibid.*, vol. xiii., page 227.

Mr. Ross (Larkhall) thought that there was one item that was in favour of jigger-screens, viz., thin pieces of coal were still left in. They passed over the jigger-screen, while with the bar-screens they passed through with the dross.

The PRESIDENT, in closing the discussion, moved votes of thanks to Mr. Hastie and Mr. Mungall for their papers. They were interesting papers, showing what had been done as regards surface-fittings in recent years. Some years ago the Institute had published a report on coal-cleaning, and the members would agree that there had been a considerable advance during recent years in the surface-arrangements at collieries, and he thought that it was interesting to have a record of these improvements from time to time.

REPORT ON THE HOME SECRETARY'S "EXPLOSIVES IN
COAL-MINES ORDER, 1896." *

By THE COUNCIL.

It is provided in the Coal Mines Regulation Act, 1896 (sec. 6) that "A Secretary of State, on being satisfied that any explosive is or is likely to become dangerous, may, by order, of which notice shall be given in such manner as he may direct, prohibit the use thereof in any mine, or in any class of mines, either absolutely or subject to conditions, and the provisions of the principal Act as to contraventions of general rules shall apply to contraventions of any such prohibitions."

By virtue of that provision, the Home Secretary issued an order, dated December 19th, 1896, absolutely prohibiting the use of any explosive other than a "permitted explosive" in the roads after July 1st, 1897, and in every part of the mine after January 1st, 1898, in all coal-mines in which inflammable gas had been found within the previous six months, and in all coal-mines which are not naturally wet throughout.

After January 1st, 1898, permitted explosives are only to be allowed subject to the conditions (1) that each charge shall have a shot-hole, and have not less than 9 inches of stemming; (2) that the method of firing shall be incapable of igniting gas or coal-dust; (3) that the firing shall be done only by a competent person, specially appointed and independent of the coal-getter or person using the explosive; and (4) that the explosive shall be used only in the way directed in the schedule attached to the order.

Further, after July 1st, 1897, no explosive shall be used in main intakes unless all workmen have been removed from the seam and all seams communicating with the shaft on the same level, except the shot-firer and such other persons, not exceeding ten in number, as are necessarily employed at certain specified duties.

The schedule attached to the order details the explosives which are permitted, their composition, and the conditions of their use. The

* *Trans. Fed. Inst.*, vol. xiii., page 18.

explosives are :—ammonite, ardeer powder, bellite No. 1, bellite No. 3, carbonite, dahmenite A, electronite No. 2, kynite, roburite No. 3, and westfalite.

Considerable dissatisfaction having been expressed at the order on account of its stringency, as well as the expense involved in giving effect to it, the Council thought it desirable to get some definite information as to the effect it would have on the working of mines, and it was arranged to have some trials made by some of the members of the Council, comparing the existing methods of blasting with those required by the order. A few trials were made, and the result of these were reported to the Institute at the General Meeting held on April 15th, 1897. After some discussion it was remitted to the Council to take the matter into further consideration. Accordingly the Council considered the matter and agreed to issue to the members the result of the trials already made, and invite them to make further trials and report the same to the Council. In response to this invitation a number of additional reports have been handed in, and Tables I. and II. contain an abstract of the whole of the results, including those reported at the last General Meeting and those received since.

A report from Bothwellpark colliery, without giving particulars, stated that there was an increase in the proportion of dross of 25 per cent. with carbonite as compared with powder in blasting coal; while in brushing with carbonite the sides were left ragged, and required much more trimming than when powder was used, and the material was broken too small to be satisfactory for building.

On referring to Table I., which shows the results in blasting coal, it will be seen that of the ten trials therein described, eight show that the percentage of dross is greater with the permitted explosives than with powder; and in regard to cost, all, with one small exception, show the cost by the use of the permitted explosives to be the greater.

The results in brushing, as brought out by Table II., show the cost, in all the seven trials reported, to be greater with the permitted explosives than with powder; and all are at one as to the shattering of the material blasted, and the ragged condition in which the high explosives leave the road-sides.

In comparing the costs, it should be borne in mind that it will probably be necessary to fire all shots under the conditions of the order by electricity. This will be a further element of expense not taken into account in these trials.

TABLE I.—COMPARISON OF POWDER WITH "PERMITTED EXPLOSIVES" IN BLASTING COAL.

No.	Name of Colliery.	Name of Coal-seam.	Kind of Working.	Extent of Trial.	Tons Worked.	Headle.	Percentage of Coal.	Percentage of Dress.	Explosive Used.	Quantity and Price of Explosive Materials.	Cost per Ton.
1	Auchinraith	Virgin	Room 12 ft. by 6 ft.	9 days	20-35 1½	1½	68-0	32-0	Powder	6½ lbs. at 4½d.	d.
2	Minwood	"	"	9 days	18-90	—	57-4	42-6	Roburite	4½ lbs. at 10½d.	1-27
	"	Splint	Room 9 ft. by 5½ ft.	6 days	29-75	1½	77-6	32-4	Compressed powder	7½ lbs. at 3½d. and fuz 10d.	2-5
	"	"	"	6 days	25-85	1½	70-7	29-3	Carbonite	4 lbs. at 10d., 14 detonators at 1d. and fuz 10d.	1-13
3	Whistleberry	Ell	Room 12 ft. by 4½ ft.	2 breakings	18-45	1½	72-2	27-8	Powder	2½ lbs. at 10½d. and fuz 5d.	2-20
	"	"	"	2 breakings	17-10	1½	67-7	32-3	Kynite	1½ lbs. detonators, and fuz	0-84
	"	"	Room 12 ft. by 5 ft.	—	78-00	—	—	—	Kynite	8½ lbs. at 9d., 19 caps at 3d. 6d per 100, and 66 feet fuz at 1d.	0-70
4	Lanemark	Eight-feet	Room 10 ft. by 5 ft.	111 ft. of room	190-00	—	—	—	Powder	143 lbs. at 3½d.	1-32
	"	"	"	47 ft. of room	87-75	—	—	—	Roburite	59½ lbs. at 11d., 88 detonators at 1d., and fuz 1a. 2½d.	2-63
5	Govan	Main	Longwall 3½ ft.	—	76-25	1½	73-0	27-0	Compressed powder	6½ lbs. at 4½d.	5-62
	"	"	"	—	163-25	1½	71-3	28-7	Kynite	9 lbs. at 9d., 37 detonators at 3d. 6d. per 100, and 106 feet fuz	0-37
	"	"	"	—	159-80	1½	71-3	28-7	Carbonite	9½ lbs. at 9d., 39 detonators, and 94 feet fuz.	0-70
6	Westburn	"	Room 11 ft. by 7 ft.	3 days	30-95	1½	78-6	21-4	Compressed powder	7½ lbs. at 4½d.	1-09
	"	"	"	3 days	29-50	1½	79-6	20-4	Carbonite	5 lbs. at 9d., and 6 detonators at 40s. per 1,000	1-63
7	Glenclelland	Virtuewell	Longwall	20 days	40-50	1½	83-6	16-4	Powder	6½ lbs. at 3½d., and 75 feet fuz at 4d.	1-037
	"	"	"	18 days	35-80	1½	69-6	30-4	Kynite	5½ lbs. at 9d., 30 caps at 1d. 4d per 100, and 76 feet fuz at 1d.	1-94
8	Gateside	Main	Longwall 3 ft.	5 days	21-45	1½	60-7	39-3	Compressed powder	2½ lbs. at 4½d.	0-47
	"	"	"	5 days	22-55	1½	61-4	38-6	Roburite	1½ lbs. at 10d., 11 detonators at 40s. per 1,000, and fuz 1a.	1-13
9	"	"	Room 12 ft. by 3½ ft.	5 days	23-75	1½	69-4	30-6	Powder	4½ lbs. at 4d.	0-80
	"	"	"	5 days	19-85	1½	66-7	33-3	Roburite	2½ lbs. at 10d., 10 detonators, and fuz 1a.	1-92
10	Broadrigg	—	Room 12 ft. by 4 ft.	5 days, 2 men	23-60	1½	73-5	26-5	Compressed powder	Powder and fuz	1-35
	"	—	"	5 days, 2 men	25-40	1½	69-5	30-5	Bellite	Bellite, caps and fuz	2-87

TABLE II.—COMPARISON OF POWDER WITH "PERMITTED EXPLOSIVES" IN BRUSHING (MAKING HEIGHT).

No.	Name of Colliery.	Name of Coal-seam.	Nature and Dimensions of Brushing.	Extent of Trial.	Explosive Used.	Quantity and Price of Explosive Materials.	Cost per Cubic Foot of Brushing.
1	Newton and Hallside	Main	Sandstone, 3 ft. 3 ins.	Holes. 9 Ft. of R. way 39	Powder and roburite	Powder, 30 lbs.; and roburite 13 lbs.	d. 3-77
2	"	"	"	9	Roburite	20 lbs.	6-47
	"	Ell	Blaes, 3 ft. 3 ins.	4	Compressed powder	9 lbs.	2-6
	"	"	"	4	Roburite	43 lbs.	3-4
3	Govan	"	"	Ft. of R. way 135	Compressed powder	29 lbs. at 3'08d.	—
	"	"	10 ft. by 3 ft.	3,019	Kynite	104 lbs. at 9d., 30 detonators at 3s. 6d. per 100, and 60 ft. fuze at 8d. per 48 ft.	0-029 (a)
	"	"	"	114	Carbonite	94 lbs. at 9d., 18 detonators, and 54 ft. of fuze	0-042
4	"	Main	"	100	Compressed powder	21 lbs. at 3'08d.	0-046
	"	"	"	84	Kynite	321 lbs. at 9d., 61 detonators, & 133 ft. of fuze	0-045 (b)
	"	"	"	299	Carbonite	161 lbs. at 9d., 33 detonators, & 96 ft. of fuze	0-062
5	"	Humph	Blaes, 8 ft. by 3 ft.	157	Compressed powder	184 lbs. at 3'08d.	0-056
	"	"	"	58	Kynite	284 lbs. at 9d., 46 detonators, & 133 ft. of fuze	0-054 (c)
	"	"	"	156	Carbonite	394 lbs. at 9d., 75 detonators, & 253 ft. of fuze	0-120
6	Bent	Main	Fakes, 8½ ft. by 4½ ft.	37½	Compressed powder	114 lbs. at 3'36d., and fuze 3d.	0-140
	"	"	"	23½	Ammonite	44 lbs. at 1s., fuze 3d., and caps 2d.	0-015 (d)
	"	"	Ironstone 9 ins., & Fire-clay 2 ft. 9 ins., 3½ ft.	3 shots 411	Compressed powder	84 lbs. at 4d., and 9 feet of fuze at 4d.	0-032 (e)
7	Glenclelland	Virtuewell	"	3	Kynite	54 lbs. at 9d., 3 caps, and 5 ft. of fuze 2d.	0-086 (f)
	"	"	"	3	Kynite	54 lbs. at 9d., 3 caps, and 5 ft. of fuze 2d.	0-170 (g)

(a) When Kynite is properly balanced, it does the work and squares the sides as well as powder; when the charge is too small, it does nothing; when too large, it cuts through the brushing in a line with the hole. Carbonite takes down the rock irregularly, no matter how the hole is charged. If the charge is too small, it caves under the charge, leaving the front of the brushing untouched.

(b) The effect of Kynite on squaring the roads is similar to that of powder. Carbonite cuts over the buildings (pack-walls), and the top of the brushing is left ragged and projecting over the roads, giving the men more work in squaring by pick and wedge, which they object to.

(c) Kynite gives less work in squaring the sides of the roads than carbonite.

(d) 170 cubic feet of building per foot of hole bored.

(e) 70 cubic feet of building per foot of hole bored.

(f) Wages 0'64d. per cubic foot.

(g) Wages 0'73d. per cubic foot. Kynite did not work so well as powder; it left the sides of the road more ragged; brushing material smaller; and left more work for workmen squaring the sides.

Mr. J. T. FORGIE (Bothwell) said that Messrs. Baird & Company had had two years' experience of the use of carbonite in three or four of their collieries, and the results had been very much as borne out in the report regarding Bothwellpark colliery. At first, they made up their minds to introduce a safety-explosive; and although it had scarcely satisfied them, there was less flame than from powder. He did not say that fact proved its safety, for there were many other ways in which it might be dangerous; and if these high explosives were put to the same test as powder, they would, perhaps, not show themselves to be much safer so far as life and limb were concerned. There was no doubt that there was less flame than with powder; but it was his opinion—with due precautions to see that the place was thoroughly clear of gas before the shot was fired, and that there was no dust—that there was no real danger with powder, and it was to be hoped that the Home Office order, in its amended form, would be a little more broad in its application to the different conditions of mines. There was no doubt that the order as it existed would have increased the costs at many collieries in which it was practically safe to use gunpowder. He did not think that the tests, as reported to the Council, were very reliable, and the only proper test was a long one. So far as carbonite was concerned, he had not found the cost greatly increased by its use; the brushers were paid $\frac{1}{4}$ d. per ton extra, and if fired by electricity, it would be increased by 1d. or $1\frac{1}{2}$ d. However, in the long run he did not know that cost would be a very great element. The great drawback was the ragged state in which the brushing would be left, and he was doubtful if the safety to life and limb from explosions would not be counteracted by the greater danger from falls from the roof and sides. He hardly used any other explosive than the one he had mentioned, and could not say what the increased percentage of cost would be compared with others.

Mr. JAMES GILCHRIST (New Cumnock) said there could be no doubt that the Order would add a great deal to the cost of getting coal. A petition had been presented to the Home Office from the Gunpowder Trade Association, in which it was stated that with a high class of powder blasting would be as safe as with high explosives. It was to be hoped that the Home Secretary would take an early opportunity of testing the safety of high-grade powders. Little had been said as to the extra cost of putting on shot-firers; it would, however, amount to a considerable sum, as he did not suppose that a shot-firer would be able to fire more than from 24 to 30 shots a day, and in appointing a shot-firer they required to have an experienced man. Mr. H. Hall stated that the extra cost of using safety-explosives was 0·81d. more than when

using powder.* That might be true in some cases, but he thought that in Scotland it was a little under their experience, and in an English coal-mine, with which he was connected, the cost was very much higher than when gunpowder was used.

The PRESIDENT said that there was one point that had not been referred to, viz., a comparison between the different classes of safety-explosives. There were practically two classes of these: nitro-glycerine compounds and ammonium-nitrate explosives. Perhaps some of the members could say something as to the comparative merits of these two classes, because if the order came into force they would have to consider which they were to adopt.

Mr. JAMES GILCHRIST said that since he had reported to the Council he had tested electronite, and found it was similar to roburite, but it had more the action of gunpowder than any explosive that he had seen. Those who worked with it were well pleased with it, and there were no bad fumes. The respective costs were: roburite, 5·62d. per ton, and electronite, 5·71d. per ton. There was no holing where it was used, the material being blown out of the solid.

The PRESIDENT said, in connexion with Mr. Hall's paper which had been referred to, that it was remarkable that there was not one single gas explosion mentioned that was due to the use of powder, and that most of the accidents given as due to the use of explosives might have happened with any explosive. There was a striking statement in the report of the Gunpowder Trade Association as follows:—

Although the high explosives formed only 10 per cent. of the total consumption, they caused over 25 per cent. of the deaths in handling and 69 per cent. of the deaths by explosions in shot-firing, thus indicating that the fatalities and injuries in the use of high explosives are immensely greater than the ratio number due to the quantities consumed, and as a fact they cause much greater loss of life than gunpowder.

If this statement were true, it indicated that the danger from the actual handling of safety-explosives was much greater than from the handling of powder. It seemed to him that Mr. Hall had completely failed to prove his case, and there was little doubt that with the use of the new explosives, if the experiments made in Scotland had any weight at all, there would be an increase in the cost of production both as regards the use of the explosives themselves and on account of the additional percentage of dross, and that without any advantage in the way of safety.

* *Trans. Fed. Inst.*, vol. xiii., page 4.

He apprehended danger from the freezing of nitro-glycerine explosives just as there was danger from the careless use of powder.

Mr. MARTIN (Niddrie) said that at Niddrie collieries they used no powder at the face, but they had a good deal of stone-work, in connexion with which a good many representatives of safety-explosives had made trials. The result was that they had all failed to displace gelatine, which had been used by them for many years. He did not think that there had been a single accident with it. However, he thought it was in the prohibited list, and he should like to know if, in the event of this being so, any member could recommend some explosive in its place that would be as safe and as easily handled.

Mr. FINDLAY (Glasgow) said that although carbonite was liable to harden in cold weather, there was no difficulty whatever in bringing it back to its original condition by the use of simple and effective appliances. The difficulty was to discover an explosive that would not harden, as all nitro-glycerine compounds, although the most effective for blasting purposes, were liable to harden or freeze in cold weather. He stated that a variety of experiments conducted in various parts of the country had shown that carbonite was the explosive compound nearest to blasting-powder in producing round coal that had yet been discovered. Ardeer powder was of less strength and therefore more effective for softer coal. With regard to Mr. Martin's remarks about the difficulty of obtaining explosives to do the heavy work of driving mines, he (Mr. Findlay) said that he was not authorized to make any statement, but he knew that Nobel's Explosives Company had done their utmost to have certain gelatine compounds included in the list of "permitted explosives."

The discussion was adjourned.

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION
OF ENGINEERS.

GENERAL MEETING,

HELD IN THE ASSEMBLY ROOMS, TAMWORTH, APRIL 3RD, 1897.

MR. M. H. MILLS, PRESIDENT, IN THE CHAIR.

The following gentlemen were elected :—

MEMBERS—

MR. JAMES BUSH, Mining Engineer, The United African Collieries, Ltd.,
Eikiboom, Middelburg, Transvaal.

MR. THOMAS ROWBOTHAM, Mechanical Engineer, Shaw Heath, Stockport.

MR. JOHN THOMAS TODD, Mining Engineer, Blackwell Collieries, Alfreton.

ASSOCIATES—

MR. ROBERT COUPE, Under-manager, Tibshelf No. 1 Pit, Alfreton.

MR. JAMES DAY, Under-manager, Balborough Colliery, Clowne, Chesterfield.

STUDENT—

MR. WILLIAM HENRY HARDY, Mining Student, Green Hill, Eastwood,
Nottinghamshire.

MR. G. J. BINNS read the following paper "On the Occurrence of
Certain Minerals at Netherscal Colliery, Leicestershire":—

ON THE OCCURRENCE OF CERTAIN MINERALS AT NETHERSEAL COLLIERY, LEICESTERSHIRE.

BY G. J. BINNS, F.G.S., AND GEO. HARROW, PH.D.

The writers desire to place upon record the occurrence of the following minerals at Netherseal colliery, Leicestershire.

It may be mentioned that the Coal-measures in this locality are overlaid unconformably by Permian and Triassic rocks, the former sparingly developed and the latter of considerable thickness. Also that the measures generally are much subject to faulting, frequently of an abstruse and unusual character.

1. *Sphalerite* (sulphide of zinc, ZnS) occurs as small crystals in cracks, passing through bands and nodules of clay-ironstone, which are found at numerous horizons of the Coal-measures, not only in the neighbourhood of faults, but among regular beds. In the mass it is black, but in thin flakes it is translucent, with a brownish tint. The composition is—

	Per Cent.
Zinc, Zn	63·20
Iron, Fe	2·11
Calcium, Ca	0·50
Magnesium, Mg	0·36
Sulphur, S	33·91
	100·08

A minute yellow precipitate, too small for identification, was considered to be probably cadmium.

2. *Siderite* (carbonate of iron, FeCO_3 , ? ankerite) was determined as occurring in irregular detached crystals, intimately associated with sphalerite; colour, white, changing on exposure to buff. There was not sufficient for analysis, but another sample associated with detached groups of crystalline galena gave the following composition:—

	Per Cent.
Carbonate of calcium, CaCO_3	53·0
Carbonate of iron, FeCO_3	23·3
Carbonate of magnesium, MgCO_3	20·8
Gangue	1·1
Undetermined	1·8
	100·0

So far as the crystals could be identified, they appear to be obtuse rhombohedra, and this mineral may therefore be considered as ankerite.

3. *Barytes* (sulphate of barium, BaSO_4).—Mr. A. Pringle, of the Museum of Practical Geology, determined the presence of this mineral on the edges of a vein passing through the roof-rock of the eureka coal-seam. It exists as overlapping plates, associated with calcite, and varies in colour from milky-white to pink. Another specimen is translucent, of pale green colour, and occurs in two parallel plates, $\frac{1}{16}$ to $\frac{1}{8}$ inch in thickness, in the centre of a vein of crystalline calcite, 1 inch in thickness (specific gravity of barytes, 4.38). This also came from the eureka rock, in which its occurrence with calcite appears to be not infrequent.

4. *Galena* (sulphide of lead, PbS).—About the year 1874 or 1875 one of the writers found in a band of clay-ironstone a minute crystal, which he believed to be of this mineral; but it was lost, and could not be identified. Lately, however, a remarkable deposit has been met with in a fault in the roof of the eureka coal-seam. This rock is a close-grained grey sandstone, with an argillaceous (sometimes ferruginous) cement, very much subject to false-bedding, which is frequently marked by fine streaks of carbonaceous matter. The fault-slip runs east and west, and throws up to the south about 9 inches. The vein is not crystalline or clearly defined, and varies in thickness from 6 inches downwards. The gangue is clay, and the galena occurs in masses of irregular height and length, up to $1\frac{1}{2}$ inches in thickness. Its lateral extent was proved to be at least 75 feet. The fault passes down into the coal-seam, which is about $3\frac{1}{2}$ feet in thickness; but the galena does not continue beyond the roof rock.

One of the writers made an analysis of this ore (specific gravity 7.39), with the following result:—

				Per Cent.
Sulphide of lead, PbS	...	...	...	98.42
Sulphide of iron, FeS	...	...	...	0.27
Sulphide of zinc, ZnS	...	...	...	0.41
Gangue	...	...	...	0.46
Undetermined	...	...	...	0.44
				100.00

In spite of very careful examination no silver was found, but in a subsequent investigation, by the aid of the spectroscope, Prof. Hartley, F.R.S., and Mr. Ramage identified copper, silver, iron, sodium, and potassium.

Another interesting occurrence of galena was recently met with in the eureka rock, where a small vein, about $\frac{1}{8}$ inch in thickness, of ankerite was exposed by a fracture of the stone. Perfectly covered with glistening white mineral, which was studded at intervals of about 2 and 3 inches with small groups of galena-crystals, approximately $\frac{1}{8}$ inch in diameter, this specimen presented an unusual and brilliant appearance. So far as could be ascertained, the vein extended at least 9 feet horizontally and 2 feet vertically, but its upward extension was not proved.

5. *Copper* (chalcopyrite).—Many years ago Mr. E. Hague observed the presence of copper pyrites in this mine, and it has recently been determined as existing in minute detached crystals, plentifully scattered along the edges of a vein of calcite, about 1 inch in thickness, which was found traversing the eureka rock.

As mentioned above, copper occurs also associated with galena.

Mr. WILLIAM SPENCER (Leicester) said he had frequently found lead-ore, supposed to be galena, in the fissures of faults in the Coal-measures. He remembered one considerable lump, spherical, and, he thought, water-worn, that he supposed might have been rolled from the Carboniferous Limestone measures about 25 miles off.

Mr. G. E. COKE (Nottingham) thought it was an interesting fact that most of the minerals described in the paper were found in the Mountain Limestone. He was well acquainted with the Mill Close lead-mine, and the vein always followed faults; barytes, copper, and other minerals mentioned by Mr. Binns being associated with it. It had been suggested that the lead-ore was deposited by heated gases escaping along the fault-slip. At Ripley colliery, lead veins were found passing through a coal-seam without any signs of heat in the surrounding coal.

Mr. A. H. STOKES (Derby) said he had seen a vein of lead-ore in a coal-seam in northern Derbyshire. Lead-ore was found also in the roofs of coal-seams in southern Derbyshire.

Mr. BINNS remarked that lead-ore was only found in the roof.

Mr. STOKES remarked that Mr. Binns spoke of a specimen of barytes as being of a green colour: might not that be due to the presence of copper?

Mr. LONGDEN proposed a vote of thanks to Mr. Binns and Dr. Harrow. The members were indebted to Dr. Harrow for the analyses, which required much time and care.

The motion was agreed to.

Mr. BINNS, in responding, said that the presence of the minerals described in the paper was not considered by the authors as unique, but they thought it was desirable that their existence should be recorded. He was not previously aware that galena occurred in such quantities in coal-seams, and he was pleased to have been the means of placing this and other matters on record.

Mr. G. J. BINNS read the following "Notes on Auxiliary Haulage at Netherseal Colliery":—

NOTES ON AUXILIARY HAULAGE AT NETHERSEAL COLLIERY.

By GEORGE J. BINNS, F.G.S.

Notwithstanding the valuable paper recently published in the *Transactions* of The Federated Institution of Mining Engineers,* and the lengthy discussion which followed, the writer ventures to think that the subject is not yet completely exhausted, and begs to lay before the members of this Institution the following examples of mechanical auxiliary haulage under somewhat unusual conditions.

It is not intended to include a comprehensive account of an auxiliary haulage-plant for the whole of a colliery; partly, because that has already been done in the paper referred to, and partly because the system in vogue at Netherseal colliery includes both horse and mechanical power. This admixture, which the writer considers should not be arbitrarily condemned, is due to various causes which need not be here detailed: in a new pit, especially one in which the topographical conditions are favourable, it is no doubt easy to commence, *ab initio*, with engine-power exclusively; but, in the present case, although most newly laid-out districts have been carried out on this plan, the circumstances are such that each part must be considered on its merits, and a scheme devised which will, as nearly as possible, meet the various conditions which exist.

(1) Some years ago, the continuity of the working-face in the main coal-seam at this colliery was disturbed by the existence of an anticline whose axis runs in the direction *OP*, Fig. 1 (Plate XIV.), causing the seam to dip at an angle of 1 in 3 in the direction *f e*. The distance from the shaft was approximately 1 mile, the roads tortuous and of varying grade, and no appliances existed for the application of mechanical power. For some short distance horses were used, but this means of traction speedily becoming impracticable the district was abandoned. As the scouring of gob-roads in this seam is prevented by a strong liability to spontaneous combustion, it was necessary in order to reach the abandoned face from a lower seam to drive a pair of cross-

* Vol. xii., page 257.

measure drifts, one of which is shown at *KC* in Fig. 1 (Plate XIV.). The main coal-seam was struck at *C*, and operations were commenced for proving its continuation on the full dip. A compressed-air hauling-engine, very similar to those described by Mr. Galloway,* and consisting of two cylinders (6 inches in diameter by 10 inches stroke), driving, by means of helical gearing and jaw-clutches, a pair of drums $2\frac{1}{2}$ feet in diameter, was erected at *A* in a heading, no expense being required for an engine-house. With the assistance of this hauling-engine, headings were driven as shown, the whole of the haulage—as may be assumed from the various angles of dip—being carried out by mechanical power. Some distance beyond the point *B*, Fig. 1 (Plate XIV.), a fault cut out the seam, when stalls were headed out, and the coal worked towards the shaft. The empty tubs, which weigh $4\frac{3}{4}$ cwts., and hold when full about 12 or 14 cwts. of coal, are lowered down the road *CD* by a crucible steel-wire rope ($\frac{1}{2}$ inch in diameter) and are stopped in the stall at any point where it is desired to load. The coal-face is kept at such an angle as will allow of the tub running in and carrying the rope, but a fault near the far end of the stall *E*, Fig. 1 (Plate XIV.), caused the dip to be reversed, and, in order to overcome this difficulty, the tub is run as far as gravity will take it; the main rope is then detached and coupled to the end of a loose rope long enough to reach to the far end of the stall (where it passes round a pulley slung to a firmly-fixed prop) and back again to opposite its other end, which is fastened to the tub. The engine is then started, and the tub pulled uphill to the far end, where it is filled. On its return it drags the loose rope back to its original position, and comes to rest opposite the shackle of the main rope, to which it is then attached and hauled to its destination. The same system has been frequently applied to driving rise heads as at *Fh*, and *ef*.

In addition to serving the two stalls *E* and *B*, the hauling-engine at *A* works the road *GH*, a section of which is shown in Fig. 2 (Plate XIV.). This heading crosses a fault, through which it was necessary to drive the rising stone-head *HJ*, and in this case also the loose rope was employed. The stone from this drift was taken up *HG* and lowered into the stalls *B* and *E*, where the hauling-engine delivered it well back into the goaf. The coal-seam is of considerable thickness and valuable quality, and it is naturally desirable to obtain the maximum yield per acre. The tub is run into the waste and partly off the rails, so that the impetus of the heavy load (with a little assistance from the miners) tips out most of the dirt. When all is out, the hauling-engine pulls the waggon

* *Trans. Fed. Inst.*, vol. xii., page 259.

back on to the rails, where it is loaded with coal. By this means, material for packing is provided, *débris* is disposed of, gob-fires are prevented, and the men work in safety at the seven feet of over-coal which exists. Another road occasionally worked by the hauling-engine is the self-acting incline *KC*, on which during the day materials and stone are brought up by the descending coal-waggons. At night, however, when this may not be possible, the rope from *A* is passed partly round a pulley at *C*, and lowers a waggon to *K*, where a tub of stone, clay, or whatever may be required, is attached and hauled to *C*, whence it is run into the stalls.

The road *GLN*, Figs. 1 and 3 (Plate XIV.), is also part of the same haulage-system, with a branch at *m* to *n*. The coal from the two heads *ba* and *dc* is jigged down to *a* and *c*, and the scheme for working *NLC*, which is of varying grade, is fully described elsewhere.

The ropes which haul the loaded tubs at a speed of 1.65 and 1.95 mile per hour on the roads *CF* and *CD* are of patent crucible steel, $\frac{1}{2}$ inch in diameter, and last 26 months. It is preferable when starting a new road to put on an old rope, as, even with the greatest care, it is impossible to tell exactly where pulleys will be required, and consequently a new rope may become damaged before it is bedded to its work. This little precaution avoids the difficulty mentioned by Mr. Galloway.*

(2) From the point *A'* in Fig. 1 (Plate XIV.) a stone-drift was driven, rising 24 inches to the yard, to prove the existence of coal at *B'*, where it was found of excellent quality and thickness. A drift *C'D'* was then commenced, cutting the measures at 1 in 3, to form a working-road. Pending the completion of *C'D'*, it was desired to proceed with coal-heading from *B'*, and the output must be delivered down *B'H'A'*. A small hauling-engine (6 inches in diameter by 10 inches stroke) at *J'* had already been utilized to drive the dip road *A'J* as far as *K'*, from which point it was continued to *J* by horse-haulage, and one drum of this hauling-engine was devoted to the engine-plane *B'H'A'*. The rope passed from the hauling-engine round *C'A'H'* and half round a pulley at *B'*: by this means the output from the two headings at *F'* and *E'* is dealt with. The other drum carries a rope, which passes straight up the road *C'D'*, half round a pulley at the top (which is moved as required, and well protected from damage which might be caused by shot-firing), and lowers the stone from *D'* to *C'*. As compressed-air rock-drills are used, and 25 to 30 charges of high explosives are fired during the 24 hours, a large amount of dirt is extracted. When the power-drills are not working, compressed-air jets are used for ventilation.

* *Trans. Fed. Inst.*, vol. xii., page 269.

To revert to B' (Fig 1, Plate XIV.). The output from the headings $B'E'$ and $B'F'$ was for some time removed by means of hand-winches, but this method was slow and excessively costly, so a hauling-engine was fixed at G' . The reason for choosing this site was that, owing to a fault at G' , the road dips in both directions from that point. To haul from E' , the rope passes to the right of the hauling-engine, and round the corner to the left. Coal from F' is hauled to G' , the rope is then detached and fastened to the other end of the tub, which is lowered to B' . When a communication has been effected between the termination of the rock-drift $C'D'$ and the coal-head $B'F'$, the output from E' will pass up to G' , and then be lowered to the new road, instead of passing, as at present, down $B'A'$, which can hardly, even by an enthusiast in auxiliary haulage, be considered a convenient or desirable engine-plane (Fig 4, Plate XIV.).

(8) In mechanical main-rope haulage (that is, where a tail or endless-rope is not employed) considerable difficulty arises when the road, instead of dipping sufficiently to carry the empty tub, either becomes level, or rises in a direction away from the hauling-engine. A case of this kind is shown in Figs. 5 and 6 (Plate XIV.). The hauling-engine at A was required, among other duties, to drive a coal-head from C to D , and to deliver the load at a . The road $aBCE$ was already in existence, and if the loose rope elsewhere described had been employed to haul the tub from B to C by a pulley at C , the main-rope shackle would have been between B and a , when the tub arrived at C , and would thus not have been, without a certain amount of labour, available for lowering down CD . A balance-waggon was therefore allowed to remain at E , with an attached rope reaching to C ; and when the full tub came up DC to C , this rope was attached to the back end. The drum then revolved and drew the load of coal to B , while the balance-waggon arrived at C , where it was kept by stops. On the return journey, the empty tub was (after its arrival at B) attached to the end of the balance-rope, and the balance-waggon was allowed to run down CE in order to drag the empty up BC on its way towards CD . Of course, if another drum had been available, a tail-rope might have been employed, but the system here described worked well, and required only one drum.

Another method is pursued on the road CLN , which branches at m to n (Figs. 1 and 3, Plate XIV.), where the loose rope forms part of the scheme. Three empty tubs with rope attached run down CL to L , where there is a short siding, at which two are detached. The third is

run down *mn* and exchanged for a full tub, which is landed in the siding. The two empties which were left are taken up *NL* by a loose rope round a pulley at *N*; but while the engine is performing this work, it also hauls three full tubs up *LC*. When it is desired to lower two full waggons from *c* and *a*, they are fastened to the loose rope passing round *N*, and controlled by the engine, which at the same time lets three empties down *CL*. Thus, except when working the road *mn*, each operation is performed in duplicate.

The remainder of the auxiliary haulage carried out at this colliery calls for no special remark, being of the ordinary type. Eight small hauling-engines are employed, the majority fitted with two drums, and cylinders 6 or 7 inches in diameter.

General Remarks.—It is difficult, if not impossible, to ascertain the amount saved by the employment of a system which owes its existence to the fact that no other means was applicable, but by assuming that horses could have been used, and estimating their cost and that of the drivers, also the extra charge involved in keeping roads repaired; a figure was arrived at in the autumn of 1893, which showed a very handsome annual saving from the use of compressed air. At that time the compressing-plant consisted of an engine with a single cylinder 12 inches in diameter by 2 feet stroke (air and steam), working at about 110 strokes per minute, and actuating two diagonal single-drum hauling-engines, each with 2 cylinders 7 inches in diameter by 10 inches stroke, and two double drum hauling-engines with cylinders 6 inches in diameter by 10 inches stroke, the average distance from the source of power being 2,988 feet. The compressing-plant was originally intended principally for providing air for power-drills, but the attractions of hauling were so great that all the air available was used for this purpose. Subsequently, owing to the apparent success of the small plant, it was decided to put down an air-compressing engine, with two cylinders 24 inches in diameter by 48 inches stroke, and thus not only to avoid an obvious danger of breakdown, but also to extend the system and have a reserve of power for rock-drilling, pumping, and ventilation.

While it is not intended, in the present paper, to make any comparison between the merits of horse and engine-traction, some of the advantages and drawbacks of the two systems may be shortly referred to. The slowly-running, regularly speeded tubs create practically no dust, and the sleepers, if rollers are provided, last until they rot away. It is not

necessary to make roads any higher than is required for the passage of a loaded tub. An engine is controlled by a reasoning human being, whereas a horse is an unreasoning brute, liable to fall, or run away, or kick, or to misconduct itself in some other way, so that life and limb may be endangered. In narrow places it is necessary to make sufficient room for a horse to turn, whereas the rope requires none. In steep dip-places the struggles of a horse must always cause a pang to the individual who carries out a policy of kindness to animals, and miners soon recognize the advantage of never being called on to "give a shove up" or possibly even to assist at the replacement in an upright position of an unfortunate pony, whose efforts to obtain a foothold upon a slippery floor have ended in his downfall. No epidemics of influenza or poisoning by noxious feed are known among engines; and in periods of short working-time, or even total cessation of work, no horsekeeping or fodder is necessary; besides which the engines work as well on Monday morning as on any other day, which spirited horses frequently do not. The adaptability of rope-haulage to all conditions will hardly be questioned, but a use for which it was not originally designed has been discovered by the stall-men, who occasionally hitch the rope on to their ringer-chains, and thus withdraw timber from the wastes. The exhaust from an air-driven engine, if it does not actually provide for ventilation, at least has a distinctly favourable effect in its immediate vicinity.

On some of the above points opinions may differ, but the writer thinks that nobody will question the advisability of having at hand a safe method of attacking an area of coal, however awkwardly situated, and that too in a manner which enables it to be worked in the best possible manner.

Some drawbacks are, of course, existent. Considerable expenditure is necessary to put down a plant of any size, and the useful effect is admittedly low: pipes are a constantly recurring necessity, and the writer has not escaped the usual difficulty experienced in maintaining pressure in small mains. It is so easy to tap a main and put in a branch pipe to feed a small engine, that eventually it is found that too much has been expected, and delay is caused by insufficient pressure.

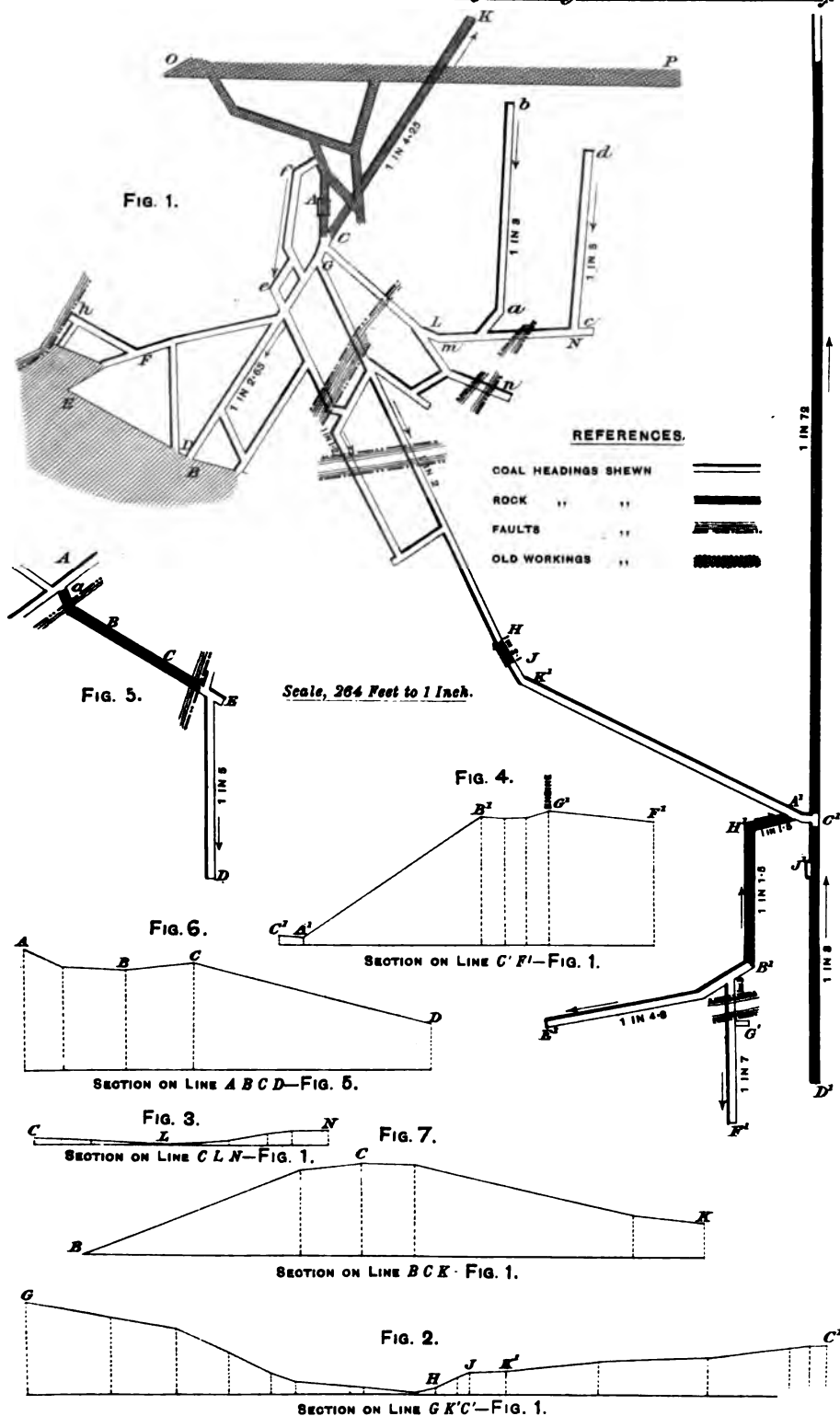
Breakdowns sometimes occur, as will always be the case where machinery is employed, and it is not so easy to repair a broken engine as to send for another horse. Roads must be provided with roller and curve pulleys, but a straight road (if the dip is sufficient) is by no means necessary. The first road worked by the writer had been driven alongside a fault, and was so crooked that the rope never approached the

centre except in its passage from one side to the other. Freezing at the exhaust-pipe is sometimes a nuisance, but this has occurred in two cases only, where the engines are close to the pit-bottom.

A serious disadvantage, which was not in existence when the plant was put down, has recently been introduced by the "Explosives in Coal Mines Order, 1896." It will be observed that each of the places where a tub has ever been hauled by a rope and mechanical power is included in the definition of a "main haulage-road" under the order. The serious disabilities attaching to a road of this description are thus shared by the coal-faces *B* and *E* (Fig. 1, Plate XIV.), by *G* to *A'* (except from *K'* to *J*, where a horse was used) by engine-planes, in fact, which have never passed more than a few tubs of dirt in the 24 hours. In other cases, the distinction sought to be drawn is equally incongruous. At the pit-bottom, the empty tubs leave the cage and gravitate to a point whence they are hauled by a small engine, such as has been already described, to the main rope; on a nearly parallel waggon-way, the full trams run by gravity when released. Along the latter, from 650 to 750 tons of mineral pass per day, and about 500 men tramp in each direction: on the former pass daily 4 or 5 persons, and a number of empty tubs, but they are hauled by a rope, consequently this is a "main haulage-road," and the other is not. If the three horses originally employed to draw the empties had been retained, no disabilities would have been incurred. It is much to be regretted, in the writer's opinion, that by recent legislation a branch of colliery engineering, which is without doubt one of the problems of the future, should be severely and unjustly penalized.

Mr. J. A. LONGDEN, alluding to the concluding paragraph of the paper, remarked that there were four of H.M. inspectors of mines in the room, some of whom he thought had recommended that the order referred to should be issued. As to impeding the working through freezing at the exhaust-ports of the compressed-air engines, his own experience was that if the ports were large enough there was not much difficulty from this source. Mr. Binns had not given much information as to his air-compressing plant, and had said nothing as to its efficiency. He thought that, whilst Mr. Binns' colliery was perhaps one of the most difficult to manage in the kingdom, it was one where electricity might have been used with great advantage. He demurred to the remark that "It is not necessary to make the roads any higher than is required for the

*To illustrate Mr. G.J. Binns' Notes on Auxiliary Haulage at Netherseal Colliery.**



passage of a loaded tub." He remembered some time ago, at a colliery in Staffordshire in which he had been invited to take an interest, finding that the only way of getting into one seam was to lie down in a long box as if he was in a coffin, through absence of height in the road, and be let down an incline of 1 in 1; he considered that if the rope broke he would be sent direct into eternity, and had declined to have anything to do with the mine. The way in which Mr. Binns ran a single wire rope round the pulley was ingenious. He did not know whether there had been any cases of over-winding; if not, the signalling arrangements must be very complete.

Mr. WM. SPENCER said he did not think it mattered much under the circumstances whether electricity or compressed air or steam was the motive power. The chief thing was that—in the difficult conditions that had been detailed—horse-haulage would have been impracticable. In including steam, he assumed a rope to be taken from the surface. Wire-ropes could be applied to a great variety of purposes, but he did not like the application of the rope for pulling out timber. He would be glad to know the experience of anyone who had applied an endless-rope for subsidiary haulage in a flat seam. He was arranging to have an endless-rope actuated from the main-rope going along the level, and to have another small endless-rope actuated by the secondary rope, and readily put in and out of gear, and going up to the face in each gateway. So far as he was aware, this had not been done before.

Mr. G. E. COKE said that, at the old Kilburne pit, there used to be a system of attaching short ropes to the endless-rope for pulling out of steep dip gate-roads. He felt somewhat diffident in mentioning Pleasley colliery in the presence of Mr. Longden, but the great advantage of employing electricity at that colliery seemed to him to be due to the facility with which power could be transmitted over long distances for auxiliary haulage.

Mr. H. R. HEWITT (Derby) remarked that the question of auxiliary haulage was next in importance to the main haulage system, and one could not be successful without the other. Of the three powers available, viz., steam, compressed air, and electricity, steam should be omitted from the controversy because of its wellknown disadvantages. He referred to a paper by Mr. Rankin Kennedy,* who criticized the electric currents used, and showed that the alternating current was the best to be used under-

* "Electrical Machinery for Mines," *Trans. Fed. Inst.*, vol. x., page 98.

ground for haulage purposes. Mr. Kennedy spoke unkindly of mining engineers for not adopting this system in preference to the continuous current, but he (the speaker) could assure Mr. Kennedy that mining engineers would always be ready to adopt modern systems; still, it was too much to expect that they would be constantly pulling out motors which, because they were 12 months old, were obsolete. Mr. Kennedy showed—and probably this was the reason for which the paper was written—how it was possible to use a motor underground without sparking. The Kennedy motor was a step in the right direction, and avoided the necessity of being enclosed in any way. When Mr. Kennedy had perfected the machine they would be pleased to hear more about it. He asked Mr. Binns the cost of ropes per ton of coal drawn, and also, if the pipes conveying the compressed-air were buried or exposed, and whether he had any trouble in keeping the air-pipes intact. Compressed-air pipes were more cumbersome than electric cables. He knew that Mr. Binns had worked coal which would have remained ungotten if horse-haulage had been used.

Mr. HARGRAVE WALTERS (Birley Collieries) said he had a good deal of haulage, and unfortunately it was all pulling uphill. With regard to auxiliary haulage, several pumps were being worked $1\frac{1}{2}$ miles from the pit bottom, and he had in use a number of ship's winches, driven by compressed-air, for pulling out of the dip workings. He would always employ mechanical power wherever he could get it, but if he had to put down a new plant he thought it would be electrically driven.

Mr. E. B. WAIN (Stoke-on-Trent) thought that Mr. Longden must have referred to South Staffordshire when speaking of the small roadways he had met with in that county. As to Mr. Kennedy's advocacy of alternating-current motors, such motors had advanced beyond the experimental stage. They were largely used, and some expert electricians would tell the members that electric power was by their adoption more economically employed and distributed with considerably less danger of sparking as they were made without brushes, and so had not that source from which danger must be expected in employing continuous-current electric motors. He would be glad if Mr. Binns would give some particulars as to the cost of ropes in his system.

Mr. H. R. HEWITT said he was quite aware that alternating-current motors were used extensively, but he did not think that they were being used underground.

Mr. A. H. STOKES remarked that he had been anxiously waiting to hear someone speak on the last paragraph of Mr. Binns' paper, but had been disappointed. He presumed that such silence was not due to the little interest taken in the subject. Mr. Binns had not given the percentage of useful effect, and possibly the explanation might be that it would be disparaging to compressed air if it were mentioned. Reference had been made to alternating-current dynamos, the use of which, in his opinion, was not yet an unqualified success. They might come into use at some future time, but that time appeared to be a little distant. With regard to sparking at the commutator and brushes, that had been got over long ago, but wherever they had wires carrying an electric current there was a danger of sparking. Men might couple and uncouple the wires, and put them together for the purpose of seeing a spark, but indiscreet workmen should be kept away from electric machines. Such sparking was not the fault of the machine any more than it would be the fault of a safety-lamp that a foolish workman might knock his pick through its glass and expose a naked light. Machines were being made which could work without the slightest danger from sparks at the commutator and brushes. As regards enclosing the whole of the motor, such an arrangement allowed the motor to get too hot; and a second disadvantage was the large air space inside the cover, which should it become an explosive mixture and be fired by a spark from the brushes, it would probably wreck the machine. Then there was the further disadvantage of never being perfectly sure that the attendant in replacing the cover had put in all the screws and made the joints absolutely flame-tight. As regards the use of electricity, 1 mile of wires could be laid down in a night, but 1 mile of compressed-air pipes could not be laid down in the same time. Mr. Binns stated in his paper that "the tub is run into the waste and partly off the rails so that the impetus of the heavy load . . . tips out most of the dirt." He (Mr. Stokes) thought that was a questionable mode of procedure, and that what might do well for a railway-tip would not perhaps do equally well in a mine. He did not agree with Mr. Binns' remarks that "the slowly-running regularly speeded tubs create practically no dust"; and did not think that the speed of the tub had much to do with it. If a dusty tub travelled along a roadway at the speed of 1 mile an hour and met a strong current of wind, it would, probably, be as free of dust at the end of its journey as if it had been travelling fast and in a slow current of ventilation. The question as to what would make a dusty road was not governed solely by the speed of a tub. The nature of the coal, the current of ventilation, and many other matters must be

taken into consideration. He concurred with other speakers in objecting to the opinion expressed in the paper that "it is not necessary to make the roads any higher than is required for the passage of a loaded tub." Influenza, which affected horses, was not known among engines, but there were other epidemics peculiar to compressed air, particularly the port-holes of the engines, which might become closed with ice, and crude attempts to remove this evil had sometimes resulted in serious consequences. He thought electricity superior as a motive power to compressed air. He objected to the attachment of a rope of the haulage system to the withdrawal of timber. The last paragraph of the paper was perhaps the most important, regarding the future use of explosives, for the writer there referred to the Explosives in Coal Mines Order, 1896, and intimated that the main haulage-road in that order would sometimes mean the working-face. That would be very inconvenient he (Mr. Stokes) admitted, but the writer went on to say that at one mine there was a roadway where 500 men passed in one direction and also the loaded tubs, but it was not worked by machinery, and therefore not a main haulage-road; but that a parallel road, on which the empty tubs were drawn up by the use of the rope, and upon which 4 or 5 persons travelled, because of the use of the rope and engine was classed as a main haulage-road. Consequently shots could be fired under less stringent conditions in the former road than in the latter. There was an answer to that. Would anyone present approve of blasting close to the pit-bottom under such conditions? If they did not wish to adopt the order, would they prefer to go back to enactments of the Mines Regulation Act, and water the top, sides, and bottom for 60 feet on either side of the shot? Managers in the district had made a great mistake in the past in taking the word wet to mean damp: it was nothing of the sort, it meant wet. He thought the members would find a greater difficulty in strictly carrying out the requirements of the Act than in complying with the order.

The PRESIDENT remarked that he was glad to hear Mr. Stokes so hopeful about the use of electricity in mines. He was not himself so sanguine, and still thought that there were many places where compressed air could be more beneficially used than electricity. Mr. Stokes said that they need not be afraid of sparking, and if the brushes of the dynamos were the only places where they need expect it, he agreed; but that was not so, as only a few months ago, at a coal-cutting machine worked by electricity, the connecting-wires were loosened through the vibration and working of the machine, and very serious sparking took place. The gentlemen who saw it had commenced coal-cutting by compressed air, rather than use

electricity. He could not help feeling that the effective power of electricity had been overestimated. It was all very well when everything was working well to try the effective power they got ; but try it over a week or a year, how much did they get by the many devices they were put to in order to use this volatile power. He was quite sure that compressed air was at present more useful in mining operations, especially in gaseous collieries, than electricity, and he would feel greater safety in many places in advising owners to put down compressed-air plant rather than electrical. He had been introducing coal-cutting machines into a mine in Yorkshire where there was a large air-compressing plant on the spot, and he could state that it worked very successfully. They had an air-pressure of 52 pounds per square inch at the engine and 52 pounds at the receiver, near to the coal-cutter, a distance of nearly $\frac{3}{4}$ mile, when the cutter was standing. Mr. Stokes made a difficulty about the formation of ice at the ports, and had alluded to dangerous remedies ; but he thought that such primitive methods no longer existed. If there was no moisture in the air there could be no ice produced, and drying the air would prevent freezing of water at the ports.

Mr. BINNS, replying to the discussion, said that he was fully aware of the danger which threatened anyone who dared at the present time to mention compressed air in an assembly of mining engineers. Electricity was one of those things which had come very rapidly to the front. In time it might come to be regarded not quite so favourably as at present. As to water freezing at the ports, this was not a serious hindrance, as large ports were used, and hardly any trouble had been experienced from this source. The loaded tubs were 4 feet 8 inches from the rails, with an additional 3 inches of height of rail-surface from the floor, making a very fair height of roadway. The rope could be stopped at any moment, and if the engine-driver did try to overwind the effect would not be very disastrous ; he could tell in a moment even if the tub was off the rails. At present props were hauled out with a chain ; but where was the difference if they were hauled out with a rope ? He thought it was safer to attach the chain to the rope, as he had mentioned in his paper. He understood that at a small colliery in Yorkshire there was auxiliary haulage by means of a rope fastened to the bottom of the ascending cage, which pulled the tubs out of a dip place. As regards the use of electricity and compressed air as rival powers, he (Mr. Binns) quoted Mr. Galloway's remarks in discussion,* to the effect that for the conditions under

* *Trans. Fed. Inst.*, vol. xii., page 277.

which the motors worked compressed air was preferable to electricity. He (Mr. Binns) said that although it was quite possible Mr. Galloway was wrong, he perfectly agreed with the opinion expressed. When the air-compressing plant at Netherseal colliery was erected it was intended primarily for rock-drilling, and at that time there was no reliable electrically-driven rock-drill in the market. The plant, with additions, was now used for haulage; and he was quite willing to admit that the percentage of useful effect was small. One crucible-steel rope mentioned in the paper had been running for over 2 years. The pipes were kept bare. They were thin iron pipes, and if buried they became corroded, as the pit was damp in places. Occasional fractures of pipes occurred, but the tubes were exceedingly elastic, and it was not an unheard of thing to have stone come down and lower the pipes even from the roof to the ground without any fracture, air passing as usual all the time. Still, pipes were sometimes broken, and this was a great disadvantage when it did occur.

He (Mr. Binns) thought that the Explosives Order was worse than the Act, because unless they had a dry and dusty road they need not draw all their men from the mine when they wanted to fire a shot on a main haulage-road. There was an engine-plane with wet sides, roof, and floor, at Netherseal colliery, and if they wanted to fire a shot they must, under the Explosives Order, withdraw every man from the mine. Because legislation in the past was defective, that was no reason why it should be defective at the present. He had written the paper with a considerable amount of diffidence, as it did not lead to any definite conclusion; but he had an opinion, which might be wrong, that when a man met with a difficulty and overcame it he might, by putting the facts on paper, help others equally unfortunately situated. He had to acknowledge the assistance which he had received from his under-manager and enginewright, who had helped him in carrying out details, which took a good deal of scheming and cogitation before they were brought to a successful termination.

Mr. W. SPENCER proposed, and Mr. LONGDEN seconded, a vote of thanks to Mr. Binns for his interesting paper, which was agreed to.

Mr. JOHN P. KENRICK read the following paper on "Sinking Operations at Kingsbury Colliery, Warwickshire":—

SINKING OPERATIONS AT KINGSBURY COLLIERY, WARWICKSHIRE.

By JOHN P. KENRICK.

The Kingsbury colliery, which is the new undertaking of the Hockley Hall and Whateley Collieries and Brickworks Company, Limited, is situate on the northern edge of the Permian measures of the Warwickshire coal-field, about 1 mile from the parish of Kingsbury, and is connected to the Midland railway by their Kingsbury branch line. Besides the Kingsbury colliery, the company possess two others, the Hockley Hall and the Whateley collieries, both situate close to each other on the main line of the Midland railway, between the parishes of Wilnecote and Kingsbury, and distant about $1\frac{1}{2}$ miles to the west or rise of the measures from the new colliery.

The seven feet coal-seam is being worked from the Hockley Hall pits, and the rider or four feet coal-seam from the Whateley pits, the present output from the two places being about 900 tons of coal per day. There are also in connexion with the Whateley pits extensive brickworks, turning out a large quantity of blue and brindle bricks, tiles, etc., of excellent quality.

The mineral leaseholds at present attached to the new pits embrace an area of nearly 2,000 acres. It is intended to work the rider and bare coal-seams, which were found at a depth of 624 feet below the surface, and the seven feet coal-seam, which is estimated to lie about 210 feet below the rider coal-seam. The strata dip to the east at an inclination of about 1 in 14.

The pits, which are both 16 feet in diameter between the walls, are 165 feet apart, a distance which affords sufficient room for machinery and plant to be placed between them on the surface, and increases the facilities for laying out the underground workings to raise as large an output of coal as possible.

The temporary winding-engine at the No. 1 or downcast pit, consisted of an engine with a single cylinder $20\frac{1}{2}$ inches in diameter, and $2\frac{1}{2}$ feet stroke, with a cylindrical drum 7 feet in diameter and $4\frac{3}{4}$ feet wide, and geared $8\frac{1}{2}$ to 1.

The winding-engine at the No. 2 or upcast pit, consisted of an engine with two coupled horizontal cylinders, each 18 inches in diameter, and 3 feet stroke, with a cylindrical drum 8 feet in diameter and $5\frac{1}{2}$ feet wide, fitted on the crank-shaft. A small rotary pump, with attached steam-cylinder, was fitted and applied as a steam-brake, as it was found that the foot-brake alone would not control the engine when lowering or raising exceptionally heavy weights, such as the sinking-pumps, etc.

The steam-pressure at the boilers was 100 lbs. per square inch, but as it was impossible to work the winding-engine at No. 1 pit with any greater pressure than 60 lbs. per square inch, the difficulty was overcome by means of a Tangye reducing-valve, and an old vertical boiler was utilized as a reservoir for the steam, by being placed between the valve and the engine.

The two engines were fixed back to back between the pits, and until the permanent range of boilers had been erected, were supplied with steam generated in 6 vertical boilers placed close to the engine-houses.

The temporary headgears were built of wood 28 feet high, the principal timbers being strengthened by transverse and diagonal pieces.

Locked-coil wire-ropes were used for winding throughout the sinking operations, and after experience of these ropes, the writer is very much in favour of their adoption for sinking purposes, as the entire absence of any twisting enabled considerable time to be saved in steadying the hoppits at the pit-bottom.

The hoppits used were of two sizes, the smaller ones being 2 feet 11 inches wide at the top, 2 feet 6 inches at the bottom, and 2 feet 8 inches deep. The larger ones were 3 feet 6 inches wide at the top, 3 feet at the bottom, and 3 feet 5 inches deep.

The pit-tops were covered with wooden drawbridges running on rails, and were pushed backwards or forwards by the banksman.

No. 1 pit was ventilated by a Guibal fan 4 feet in diameter, and No. 2 pit by a Capell fan 8 feet in diameter, the air being taken down the pits by wrought-iron pipes, 15 inches in diameter, the pipes being bolted together and fastened securely to each crib.

It will be noticed on referring to the section of strata sunk through (Appendix) that the first 240 feet consisted principally of a soft sandstone rock divided into two parts by two beds of bind and a thin seam of fire-clay. In the upper portion of the sandstone rock, calcareous conglomerate was met with in the shape of large boulders which were entirely absent in the lower part. Immediately below the sandstone-

rock is a bed of very rich red marl, 159½ feet thick, and the measures below the marl consist of alternating beds of hard sandstone, bind, stony marl, and coal.

It is seldom that Fortune visits poor mortals with both hands full, or to change the metaphor, it is always the fly in the amber that spoils everything. In this case it was the bed of soft grey sandstone-rock that was wrong. This rock is heavily watered, containing two enormous feeders each averaging 60,000 gallons of water per hour. The first feeder was met at a depth of about 135 feet, and the second one at a depth of about 192 feet from the surface.

In order to sink through these heavily watered strata, it was necessary to obtain special pumping-tackle, and after carefully considering the various types of sinking-pumps in the market, the writer decided to adopt the Evans pump. As will be seen by referring to Figs 1 and 2 (Plate XV.), this pump is of the well-known vertical Cornish direct-acting type with the Tonkins steam-cylinder valve-motion, operated, without tappets or lever-motion of any kind, solely by the action of the steam. The water-cylinders are fitted with brass-ring pistons, and the water-valves are of the Evans rotating rubber-disc type. The edges of the water-valves are serrated diagonally and are thus caused to partly rotate on their axes by the water impinging on the serrations as it passes through the gratings. This device causes all the wear to be equally distributed over the faces, and it also has the effect of sweeping off any obstructions, such as chippings of rock or stones always more or less present during sinking operations. Each pump is provided with a light wrought-iron suction-pipe, made to slide 8 feet, strongly lagged outside with wood, and bound by iron straps in order to protect it from the effects of shot-firing in the pit-bottom.

Three of these pumps were obtained, each pump being capable of raising 30,000 gallons of water per hour to a vertical height of 300 feet, when running at a speed of 120 feet per minute, with a steam-pressure of 50 lbs. per square inch on the piston. Two smaller pumps of the same type were also obtained, which were used as spare ones, and always kept in readiness to take the place of one of the larger ones, should it be stopped in order to change the valves or buckets, or require to be repacked.

The pumps were suspended in the pits by slinging-chains supported on scaffolding erected by the side of the head-gear. The chain, steam and exhaust-pipes, and water-pipes, were all braced together by iron clamps placed some 10 feet apart. No timber or attachments of any sort were required to support the pumps in the pit.

The lubrication of the pumps was effected from the surface, the lubricators being fixed to the steam-pipes, the steam thus conveying the lubricant to the cylinders.

After the pumps had been working some time, it was found that when running them at a greater speed than 120 feet per minute they knocked and jumped to a considerable extent. In order to overcome this difficulty a small atmospheric valve was fixed to the working-barrel of each pump with the result that when running at a speed of 180 feet per minute, they worked as smoothly and as steadily as when running at half that speed.

The shocks were caused by the air-vessels becoming charged solid with water. This was proved by the fact that before the small valve was fixed to the pumps, the outside of the air-vessel was wet and damp, but after the valve was attached the greater part of the air-vessel was always dry; the dryness being caused by the heat given off by the air compressed by the weight of water in the rising-main column.

The sinking of No. 2 pit was suspended while No. 1 pit was being sunk through the water-bearing strata. The thick bed of marl was reached at a depth of about 240 feet, the tubbing was put in as the sinking proceeded, and each feeder of water was successfully tubbed back.

The tubbing consisted of 4 wedging-cribs, 20 inches wide and 6 inches deep; 960 tubbing-plates of metal, $1\frac{1}{2}$ inches in thickness, and 360 tubbing-plates of metal, $\frac{7}{8}$ inch in thickness were used, the lighter section forming the upper 30 rings, there being 12 tubbing-plates in the circumference of the pit. The tubbing-plates were 4 feet $1\frac{1}{2}$ inches long, measured along the inside or lesser curve, and 2 feet deep, strengthened by three horizontal and 5 vertical ribs at the back, the smooth side of the plate facing the inside of the pit.

The horizontal and vertical joints between the plates were closed with yellowpine sheathing $\frac{1}{2}$ inch thick, into which pitchpine wedges 4 inches long were driven when all the tubbing-plates had been placed in position. The space behind the tubbing, for a distance of about 15 feet above each wedging-crib, was filled solid with cement concrete: surface-marl or earth was used for filling behind the remainder of the tubbing.

As soon as the water in No. 1 pit had been successfully tubbed back, the pumps were removed to No. 2 pit and sinking recommenced there, No. 1 pit at the same time being sunk to the coal-seam. The marl was found in No. 2 pit at practically the same depth as in No. 1 pit, and the tubbing was inserted in the same manner.

The total weight of tubbing, inclusive of the wedging-cribs placed in

the two pits before the water was effectually tubbed back, amounted to over 920 tons; and 788,000 pitchpine wedges 4 inches long, 100,000 wedges 6 inches long, 7,000 plugs, and about 8,000 feet of sheathing, were used in wedging and making the tubbing perfectly water-tight.

The sinking of the pits below the water-bearing strata was easy work compared to what had been gone through above. The pits were lined with brickwork 9 inches in thickness, the bricking-cribs which were of oak 14 inches broad and 6 inches deep, being placed 30 feet apart in the marl and 60 feet apart in the stronger ground below.

The pit-mouthing was built immediately below the rider coal-seam as shown in Fig. 8 (Plate XV.). The pit was bell-shaped from 16 to 22 feet to allow room for a pass-bye road on each side of the cages. The height from the rail-level to the crown of the arch is 17 feet, which allows sufficient space for erecting an arrangement to load both decks of the cages at the same time.

The sinking was continued down to a depth of 681 feet to form a sump. The temporary timbering of the pit-sides during sinking operations and before the bricking or tubbing was inserted was effected as follows:—

Iron rings 8 inches wide and $\frac{7}{8}$ inch thick, made in several lengths and bent to the shape of the pit with fish-plates over the butt-joints, were fixed around the pit, the top ring being carried on plugs or slung from the cribs by iron straps, the remaining rings being hung from this one by hangers, hook-shaped at each end and made of iron bars 1 inch square. The distance between the rings in good ground was about $4\frac{1}{2}$ feet, and in bad ground about 3 feet. The backing-deals, which were 9 inches broad, 1 inch thick, and from 4 to 6 feet long, were pressed tightly against the sides, by deal wedges driven between them and the iron rings, the lower length of timber being made to overlap the one immediately above it.

During the operation of tubbing and walling the pit-sides, a specially constructed stage was used. This stage was formed of 4 steel girders upon which pitchpine planks 3 inches thick were laid and firmly fastened together by cross pieces. It was suspended in the pits by wire-ropes fastened to each corner and attached to 4 double-purchase hand-crabs fixed on the surface, and by which it was raised or lowered, the bricks, mortar, etc., being sent down in the sinking-hoppits.

The above particulars are a brief description of some of the works executed or in process of execution. It was the writer's desire to have

dealt more fully with this subject, and to describe the surface-arrangements which are now in course of completion, but unfortunately the time at his disposal has compelled him to confine this paper strictly to an account of the sinking operations. He trusts, however, that some of the particulars given may be of service to those who are about to undertake the charge of similar operations.

To the writer's knowledge, no larger quantity of water or greater thickness of water-bearing strata has been sunk through in the Warwickshire coal-field, under pumps suspended in the pit.

Although the wear-and-tear of the working parts of pumps of this description is considerable and the consumption of steam large, he is of opinion that for lifts up to say 300 feet, they are decidedly preferable to the old-fashioned and cumbersome lifting-sets, owing to the facility with which they can be handled, and their small first cost.

APPENDIX.—STRATA SUNK THROUGH IN THE NO. 1 PIT, KINGSBURY COLLIERY, WARWICKSHIRE.

No.	Description of Strata.	Thick- ness of Strata.		Depth from Surface.		No.	Description of Strata.	Thick- ness of Strata.		Depth from Surface.	
		Ft.	In.	Ft.	In.			Ft.	In.	Ft.	In.
1	Soil and clay	2	0	2	0	30	Blue and grey bind	4	10	501	5
2	Yellow marl	16	6	18	6	31	Sandstone rock	13	11	515	4
3	Blue shaly clay	11	3	29	9	32	Grey bind	1	4	516	8
4	Brown sandstone	19	3	49	0	33	Yellow sandstone	7	6	524	2
5	Soft grey sandstone with black streaks and fossils...	25	3	74	3	34	Clunch and shale	5	6	529	8
6	Soft grey sandstone	6	9	81	0	35	Dark grey rock	2	8	532	4
7	Drift...	1	0	82	0	36	Dark grey bind	13	4	545	8
8	Soft grey sandstone	24	3	106	3	37	Hard rock	8	4	554	0
9	Limestone conglom- erate	9	6	115	9	38	Blue bind	4	0	558	0
10	Soft grey sandstone	15	9	131	6	39	Grey sandstone	5	6	563	6
11	Calcareous conglom- erate	18	0	149	6	40	Blue bind	17	2	580	8
12	Fireclay	1	6	151	0	41	COAL	2	6	583	2
13	Stony bind	4	0	155	0	42	Grey clunch	6	10	590	0
14	Soft bind	10	0	165	0	43	Strong dark blue bind	9	0	599	0
15	Soft grey rock	74	6	239	6	44	Light grey rock	3	9	602	9
16	Red marl	159	6	399	0	45	COAL	3	8	606	5
17	Grey bind	1	8	400	8	46	Dark brown clunch	3	0	609	5
18	Red marl	10	7	411	3	47	Strong dark blue bind with ironstone	14	7	624	0
19	Bastard red marl	39	3	450	6	<i>Rider and Bare Coal-seams—</i>					
20	Sandstone rock	5	8	456	2	48	COAL	7	0	631	0
21	Red marl	6	1	462	3	49	Dark blue clunch	3	6	634	6
22	Binds	1	6	463	9	50	Sandstone	3	0	637	6
23	Bastard marl	15	1	478	10	51	COAL and shale	6	2	643	8
24	Black clunch	2	4	481	2	52	Shale and clunch	3	6	647	2
25	Grey bind	2	10	484	0	53	COAL	6	1	653	3
26	Black clunch	3	5	487	5	54	Shale and bind	5	4	658	7
27	COAL	1	3	488	8	55	Hard rock	13	8	672	3
28	Grey clunch	4	6	493	2	56	Blue bind	5	7	677	10
29	Dark clunch	3	5	496	7	57	Black shale	1	4	679	2
						58	COAL	3	7	682	9

*To illustrate Mr. John P. Kenrick's Paper on
"Sinking Operations at Kingsbury Colliery, Warwickshire."*

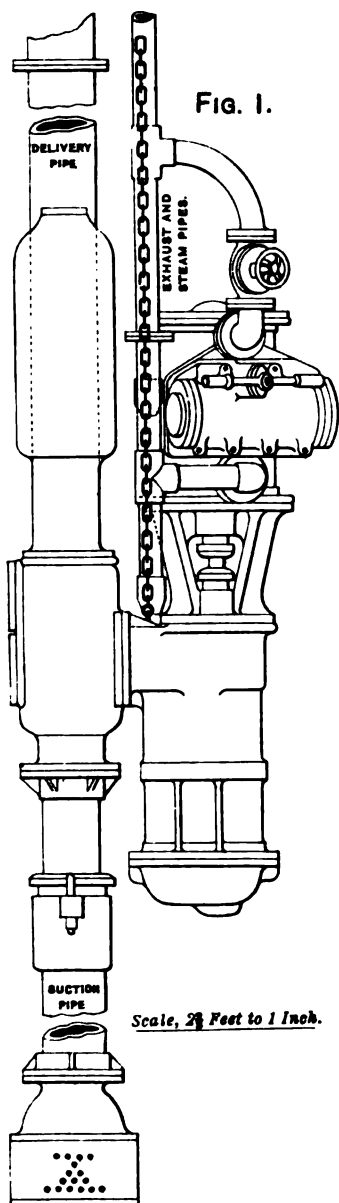


Fig. 2.

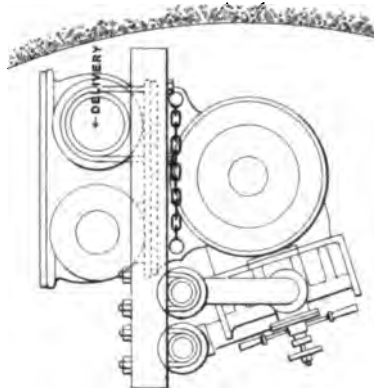
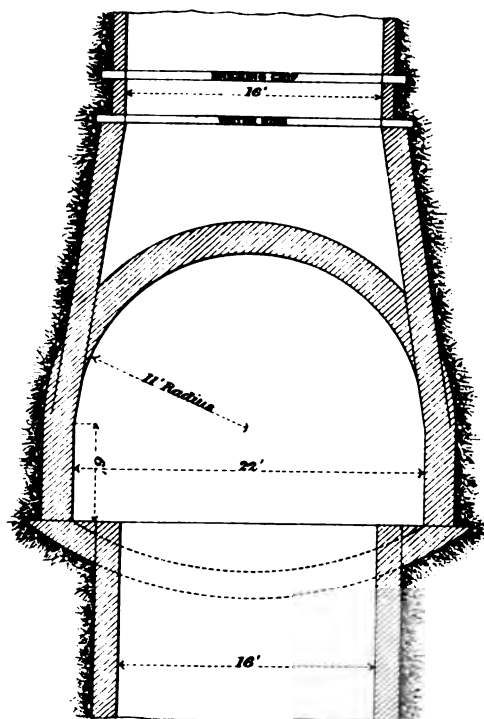


Fig. 8.



Scale, 12 Feet to 1 Inch.

Mr. J. P. KENRICK (Manchester) adding to the information given in his paper, said he thought that the Kingsbury sinking raised the question of the correlation of the seams of the South Staffordshire coal-fields with those of Warwickshire. By reference to the sections of the Hall End pits, which were situate some $1\frac{1}{2}$ miles to the east of them, it would be seen that the intervening measures between the seams of coal proved at Kingsbury were thicker at Hall End than at Kingsbury, and this tended, in his opinion, to prove that further westward these intervening measures thinned out altogether, leaving the coal-seams as one thick bed, identical with the Staffordshire thick coal-seam. The Silurian rocks were found to crop out to the surface at the village of Dosthill, forming an anticlinal, the measures dipping westward on one side and eastward on the other, and there was no doubt in his mind that coal of workable quality and thickness would be found under that large area of unproved ground lying between the exposed coal-fields of South Staffordshire and Warwickshire. The Silurian rocks at Dosthill took the form of a ridge, running north and south, elevated some 100 feet above the level of the surrounding country; they became submerged under the Kenper marls, near the village of Kingsbury, and would probably be found to dip under the Coal-measures further to the south. He thought that it would eventually be proved that the coal-fields of Shropshire, South Staffordshire, Warwickshire, and Leicestershire formed one deposit split up into small basins by intrusions of Silurian rocks.

Mr. G. E. COKE said that he had asked Prof. Hull if he had any further remarks to add. Prof. Hull thought there was some misunderstanding about his description of the relations between the coal-fields of Staffordshire and Warwickshire. His opinion was that they were the same coal-field, but that they were divided to some extent by a tongue of older rocks. He did not expect that coal would be found under Birmingham.

Mr. J. J. REYNOLDS (Manchester) thought that it had now been proved that there was a connexion between the Warwickshire and South Staffordshire coal-fields. He was of opinion that the coal-seams proved at Kingsbury were the South Staffordshire thick coal-seam, divided by thicker dirt partings, and that the seam which they proposed to work was not the rider coal of the district.

Mr. REUBEN SMALLMAN (Nuneaton) thought that Leicestershire, Warwickshire, and Staffordshire were parts of the same coal-field. Mr. Reynolds thought they had not got the rider coal-seam at Kingsbury, but

the thick coal-seam. That might be, but if it was not the rider coal-seam they stood no chance of getting it at a lower level. If the rider coal was found at all, it was found in its proper place, and after all the name was only local and was not to be taken as the real name of the coal-seam. It might be called by another name in another locality; for instance at Bedworth, it was known as the two-yards coal (5 feet 6 inches thick), below it was the bare coal-seam (2 feet 3 inches thick), then the rider coal-seam (5 feet 6 inches thick), the all coal-seam (4 feet thick), and the slate coal-seam (7 feet thick); the whole forming one series of coal-seams over 24 feet in thickness, with not more than 12 inches of parting in one place—the 7 feet coal remaining as a distinct seam.

Mr. F. A. GRAYSTON (Glascote) thought it was quite possible that these coal-seams were the thick coal-seam of South Staffordshire, but there was no positive evidence. Some years ago he ventured to correlate the seams of South Staffordshire with those of Warwickshire, and he then took the Warwickshire 7 feet coal-seam to represent the new mine coal-seam of South Staffordshire. If that were taken for granted, the rider coal-seam would represent a portion of the Staffordshire thick coal-seam. He did not think that the Kingsbury sinking had proved anything new, as he understood that there had for a considerable time been a general opinion amongst mining engineers in favour of the identity of the seams of the Warwickshire with those of the South Staffordshire coal-field. He believed that Prof. Ramsay used to consider that the South Staffordshire, Shropshire, Warwickshire, and Leicestershire coal-fields were one deposit, but whether that was so or not could only be actually proved by intervening sinkings. The fact that the strata between the coal-seams were found to be thinner at Kingsbury colliery than at Hall End colliery was not, in his opinion, evidence that the coals at the two places were not the same seams.

The PRESIDENT proposed a vote of thanks to Mr. Kenrick for his paper and the manner in which he had entertained the members that day.

Mr. T. A. SOUTHERN (Derby) seconded, and the vote was duly accorded.

Mr. E. F. MELLY read the following paper on the "Use of Steel Girders and Props in Coal-mines":—

USE OF STEEL GIRDERS AND PROPS IN COAL-MINES.

By E. F. MELLY.

It may be interesting to members to have further notes on the subject of supporting the roof in coal-mines by other means than timber, although the subject has, it is believed, been already dealt with in the *Transactions* of this and other mining institutes.

Steel Girders.—Steel girders were first used for bars, instead of larch timber, in March, 1885, at Griff colliery, and since that date timber has been very rarely used for timbering in main roads or return airways. The coal-seams are somewhat damp, and larch timber generally rotted in two or three years, even if not broken before.

The use of steel girders is so familiar now, that very few remarks and figures will suffice. The section used is 5 inches by 4 inches by $\frac{3}{8}$ inch, weighing 50 and 55 lbs. to the yard, the usual lengths being 6, 8, and 9 feet. The average cost per ton delivered in Nuneaton, from 1885 to 1893, was £5 18s., and from 1894 to 1896, £4 19s. The cost of erecting with two props (6 feet) is : 6 feet, 1s. 6d. each ; and 8 or 9 feet, 2s. each. These costs are somewhat less than the rates for larch bars of equal strength. (A larch bar of equal strength to the steel girders used would be at least 9 or 10 inches in diameter, and would cost, at 1s. 3d. to 1s. 4d. per cubic foot, about 7d. per linear foot, while a steel girder weighing 50 lbs. per yard costs about 10d.) The average cost of withdrawing steel girders from a good road is 1s. each, and from a disused road in poor repair, 1s. 3d. each. The average cost of straightening steel girders bent in use is 6d. each, for wages only. (All the wages items include the 30 per cent. advance.)

Over this long series of years, many steel girders have been lost in places where it was dangerous to attempt to withdraw them ; but recently an old main road, with the usual number of junctions and pass-byes, was stripped over a length of 1,050 feet, and out of 306 girders only four were lost ; and although the road had become very small in places, and fully half of the girders were 8 and 9 feet long, and deeply embedded in the sides, the average cost of recovering them was only 1s. 3d. each. They

had been in about six years, and only 25 had to be sent out of the pit to be straightened. Only 15 to 20 girders have been broken, out of many thousands constantly in use during the last ten years.

The writer is under the impression that the girders lose something of their strength by being straightened in the fire, and it has been noticed that straightened girders have frequently come up again badly bent; but they last so long with ordinary weights, and are so frequently taken out and replaced (sometimes when re-straightened they are put back in the form of an arch), that it is impossible, with the varying weights of roof, to say positively that they lose much by being bent and re-straightened.

Steel Props.—In 1894, an experiment was tried with steel props, formed from ordinary girders, by having the ends turned over. In a coal-seam $5\frac{1}{2}$ feet thick, with a good roof, only fourteen props were lost in a period of nine months, out of 835 in use, where a good deal of timber was broken in the ordinary course of mining. Unfortunately the coal deteriorated in character, and the working of this seam was abandoned.

In the slate coal-seam, $6\frac{1}{2}$ feet and 7 feet props are required, with the result that out of 1,550 used, 85 props have been lost over a period of two years, or about 8 per cent. per annum. The losses were nearly all due to unavoidable falls coming right up to the face, or owing to very faulty roof. Observation has shown that in this seam, a wooden prop (7 feet) from the time it is first set, while passing through the various stages of being cut down for a sprag, then used in a bruised condition as the middle piece of a "cocker," until finally broken up as a lid and thrown into the goaf, lasts about ten weeks. The result therefore of using the steel props has been to require a much larger proportion of 5 feet sprags than before, and the actual economy in this seam has not therefore been very great. The consumption of lids in all the seams has, as might be anticipated, been somewhat increased by the use of steel props.

An experiment has recently been tried in the two yards coal-seam which has a very bad roof, and where the timber, besides getting injured at the ends, splits down the middle, and is often useless even for sprags, and of very little use for lids. It has therefore by no means the same career of usefulness open for it as in the case previously described. The cost of timber in the stalls, or working-faces alone of this seam amounted to 1.53d. per ton on a large output, and although heavy falls occasionally occur, it was decided to try steel props. The result for the first three months has been most encouraging, only one of the props $5\frac{1}{2}$ feet and 6 feet long having been lost out of a total of 717 in use.

The under-manager has, however, cautiously confined their use at present to the ends of the stall nearest to the jig or jinney.

The workmen have accepted their use in the three seams without complaint, and now prefer them to timber. The weight of the steel props is 50 lbs. to the yard, and six holes, $1\frac{1}{4}$ inches in diameter, are punched in them to aid in recovering them with the ringer-and-chain.

As yet there have been no cases of the shorter props bending or breaking when in use, but about twenty of the 7 feet props have been sent up to be straightened, but none have been broken.

The relative costs of timber and steel props to-day are as follows:—

Lengths. Feet.		Wood Props, with Top 6 inches in diameter.			Steel Props.	
		s.	d.		s.	d.
5½	...	0	8½	each	...	5 7 each.
6	...	0	9	„	...	6 2 „
7	...	0	10½	„	...	7 3 „

An economy and great convenience which should certainly be mentioned, though difficult to estimate at its full amount, is the reduction in the carrying of timber into the working-places, and especially where these are approached by a jinney.

Steel Sprags.—An attempt has also been made to use 4 feet steel sprags, weighing 35 lbs. to the yard, and costing 8s. 6d. each. The workmen, however, objected to their use, and stated that they were liable to burst out unless small lids were placed on the top as a cushion against the coal, and their use was not pursued.

Corrugated Sheetting.—A somewhat novel plan of “timbering” has been adopted of necessity, owing to the peculiar characteristics of the so-called seven-foot coal-seam of the Warwickshire district. It was decided about two years ago to develop this seam, which averages about $5\frac{1}{2}$ feet thick of coal, and has a very bad fireclay floor, while the roof, after a little exposure to the air, melts away and constantly drops between ordinary barring. The seam was opened out by fore-winning to the dip, which runs about 1 in 5, and six inclines, $5\frac{1}{2}$ feet in diameter, were driven, by means of Stanley heading-machines, a distance of about 1,200 feet each to the dip. As the fireclay floor had been found to be even worse to deal with than the roof, it was decided to leave 18 inches of coal underfoot, and to support the roof (part of which was cut down by the machines) by curved, black, corrugated-iron sheets, $5\frac{1}{2}$ feet wide by $2\frac{3}{4}$ feet long, with a spring in the arch of 15 inches (Figs. 1 and 2), of No. 15 gauge (the thickest gauge that the manufacturers would undertake

to corrugate) were used. There were seven corrugations, and the weight was 58 lbs. to the lineal yard. The cost was 4s. 4d. per lineal yard (£8 8s. 6d. per ton). The cost of erection, including fixing a few bricks to make the sides solid where necessary, and packing securely overhead, was 1s. 6d. per yard in wages. The last 240 feet or so of these inclines was timbered, barred, and lagged in the ordinary way, as they had not long to stand.

FIG. 1.

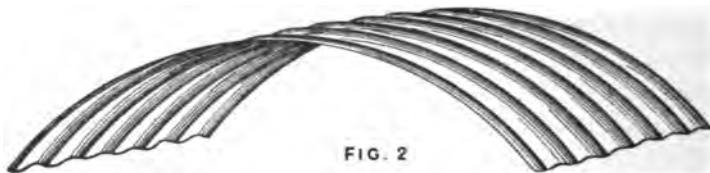
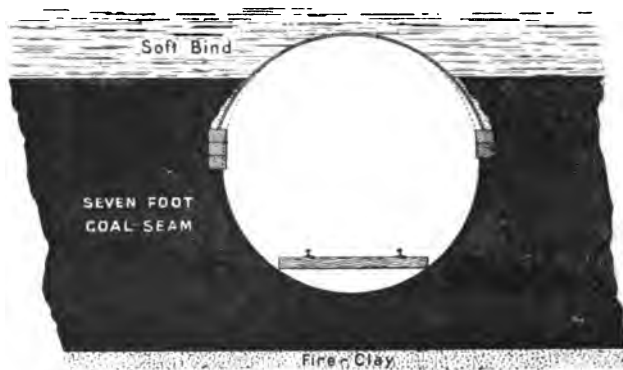


FIG. 2

The result has been that these roads stand well, and no timber whatever is required, except across the front of the manholes, but where the same road has been barred, there is constant trouble from the soft, wet roof, which rots both the timber and lagging. In a few cases the sheets have become slightly bulged and injured, and a single one has been broken in two. The rest remain exactly as when first erected one and a half and two years ago. The drawback appears to be that after once being used the sheets are of little use, except as old iron, unless there were a similar place to be supported.

Mr. J. A. LONGDEN (Stanton) said that steel bars were used at the Stanton colliery, and recently the pressure was so great that two were broken in one week right through the middle. Whether good stout

timber, under the circumstances, would have been better than steel, which snapped suddenly, was undoubtedly a question for consideration. The cost would be enormous if their experience of the week named was continuous. He would like to hear whether members using steel found any difficulty from corrosion.

The PRESIDENT remarked that he had a difficulty with the seating of girders. The girders had a tendency to cant over, and he was sure that if girders were to be used successfully, they must be properly made and not be merely a few old rails utilized.

Mr. G. H. ASHWIN (Bedworth) said that he had in use over 200 tons of steel girders and had never known one to crack, though some had been in use for 7 years. They bent a good deal at times and had to be brought up to the surface and straightened, but they had never broken. They did cant over occasionally when not properly set, but there had not been much difficulty from this cause.

Mr. W. G. PHILLIPS (Atherstone) said that he had used a considerable quantity of girders, weighing about 18 pounds to the foot, and since August, 1896, in a road which had given great trouble, some of the bars had been bent to a radius of about $4\frac{1}{2}$ feet and came down in the centre until there was not room below for the loaded tub, but he had never had a case of snapping. He always took care to strut the girders one to the other at the ends and that stopped canting. No reasonable sized timber could have been maintained in this particular road. Some of the bars had been bent, as stated, in two or three days, and had been changed three times in 8 months. He had not used steel props in the workings, but in the neighbouring collieries they had been used with some success and he intended trying them. The disadvantage of their use was the neglect of the men to draw the back props in the waste, which meant about 8s. per prop as against 9d. or 10d. for a wooden prop.

Mr. J. J. PREST (Stoke-on-Trent) said that at the collieries belonging to the Shelton Iron, Steel, and Coal Company, Ltd., they had well up to 1,000 tons of joists in use underground, chiefly 6 inches by $4\frac{1}{2}$ inches by $\frac{1}{2}$ inch, weighing 25 pounds to the foot. He made it a practice to line all new main roads and return air-roads with steel bars where some support was necessary, but he had not as yet ventured to take them into the working-face. There was no doubt whatever that steel joists would eventually supplant timber for supporting the roof and keeping down the floor in the principal roads of collieries, as they were undoubtedly much

cheaper, although the economy was more apparent than real until a sufficient weight of steel was in daily use. The North Staffordshire Coal-measures, as a general rule, were most difficult to manage, owing to the absence of strong superincumbent rock and the occurrence of numerous thick beds of marl; under these conditions, he found that steel joists were less liable to be reeled out if made end-tight, especially where the measures were heavily inclined. As soon as they were bent by the top weight, 6 or 8 inches from the horizontal plane, they simply turned them over and reset them with the bent side uppermost.

Mr. W. G. PHILLIPS remarked that it was contrary to practice in the Midland district to make the girders end-tight. Under all conditions of weight the ends should be loose, and especially so if the weight was from the side.

Mr. MELLY, replying to the discussion, remarked that he found his efficiency returns in the two-yards coal-seam were very good for the first three months, but not so good now, as they had had several falls, causing a total loss of 15 props in 6 months out of a total of about 900 props in use, and several of the shorter ones had been bent. As previously stated, several girders had broken, and one broke so peculiarly as to injure a boy, and an enquiry by H.M. inspector of mines resulted. He thought that the use of corrugated sheeting might be worth a trial in other seams with a bad soft roof.

The PRESIDENT proposed a vote of thanks to Mr. Melly for his paper.

Mr. PHILLIPS seconded the resolution, which was agreed to.

The meeting was then closed.

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION
OF ENGINEERS.

GENERAL MEETING,
HELD IN UNIVERSITY COLLEGE, NOTTINGHAM, MAY 8TH, 1897.

MR. M. H. MILLS, PRESIDENT, IN THE CHAIR.

The following gentlemen were elected :—

MEMBER—

MR. CHARLES POOLEY PROCTOR, Colliery Manager, Salterwood Colliery,
Denby, near Derby.

ASSOCIATE—

MR. JOHN HERBERT RHODES, Deputy, Pleasley Colliery, Mansfield.

STUDENTS—

MR. WALTER JENICO PRESTON, Mining Pupil, Bolsover, Chesterfield.
MR. JOHN RIGBY, Mining Student, Stanton Hill, Mansfield.

DISCUSSION UPON DR. J. HALDANE'S PAPER ON "THE
CAUSES OF DEATH IN COLLIERY EXPLOSIONS."*

Prof. F. CLOWES (Nottingham) said that the danger arising from the presence of carbon monoxide in the air of a pit had very long been acknowledged by mining engineers, and they had constantly spoken to him about the risk which they knew existed from breathing air containing this poisonous gas. A test was evidently required which would enable anyone who had to enter a part of the mine, which might be dangerous from this cause, to detect beforehand whether the air contained carbonic oxide. At present a miner or explorer first became aware of this danger by finding himself practically paralysed, and therefore unable to get out of the dangerous atmosphere which he had been breathing unconsciously for some time. Although in the chemical laboratory carbon monoxide could be

* *Trans. Fed. Inst.*, vol. xi., pages 502, 519, and 559; and vol. xii., pages 60, 102, 432, 453, and 533.

readily detected, laboratory methods would be quite unsuitable for use in the pit. Dr. Haldane, however, had experimented on various methods of detecting carbon monoxide and of giving warning beforehand of danger which might arise from breathing this gas unawares; he had artificially prepared air containing this gas in different proportions, and breathed this mixture until he had become almost helpless and unconscious. We hear with feeling of admiration of the gallant efforts put forth by exploring and rescue parties who are beset by dangers from foul gases; surely a word of praise is due to one who is doing his utmost at personal inconvenience to prevent the necessity of such risks being run by mining men. Dr. Haldane has persisted with his work, not only with the object of contributing important knowledge to science, but also in order that he might render to those who are engaged in mining the very great advantage of being able, not only to detect the presence of this gas in the air, but to arrest the danger which arises through breathing it.

Carbon monoxide is produced in many ways in the mine. The most likely source is a fire in a coal-seam, or a gob-fire, or a fire-damp explosion occurring with insufficient air or in presence of coal-dust; but it also arises from the firing of certain explosives. There are less important sources which might be referred to. The presence of the gas in mines is therefore by no means an uncommon matter. Unfortunately, most of Dr. Haldane's work has been published in journals which mining men would be extremely unlikely to see. Personally he was very glad, and he thought that the members of The Federated Institution of Mining Engineers were to be congratulated, that Dr. Haldane had been induced from time to time to record the most important facts relating to this subject in the *Transactions*.

Dr. Haldane had suggested a rough but practical test for preventing explorers, after an explosion, from remaining too long in an atmosphere containing carbon monoxide. The exploring party was recommended to carry a mouse in an open wire cage, and to constantly watch it. The mouse would suffer through breathing air charged with carbon monoxide in a twentieth of the time that a man would, so that if a mouse should fall and become practically helpless in one minute, the party might rely upon having twenty minutes to get out of the dangerous part of the mine before the air would take effect upon them. That undoubtedly was a means by which explorers might be prevented from remaining dangerously long in an atmosphere charged with carbon monoxide. One or two leading mining engineers had witnessed this experiment and were perfectly satisfied with the results.

The test, however, to which he wanted specially to refer was the test by means of blood: it was a test which had been used for many years in the chemical laboratory. But Dr. Haldane had made an attempt to put it in such a form that it could be readily used by those who had received no special training in a laboratory. Air containing as small a quantity as 0·20 per cent. of this gas was quite competent to produce serious effects of poisoning, if not death. In fact, if it was breathed for an hour, under suitable circumstances, it would produce paralysis, and if a man was thus rendered helpless, and had no one at hand to pull him out of the foul air, he would remain breathing the air long enough to produce death. Dr. Haldane mentioned that as small a quantity as 0·05 per cent. of carbon monoxide gas was quite competent to produce dizziness, partial loss of the senses, and loss of power to move the limbs. He (Dr. Clowes) was present in Liverpool when Dr. Haldane was explaining these results, and one of the scientific gentlemen present who had had a large experience in mines, said he had always given this advice, that when a man felt the effects of breathing foul air, he should take a vigorous run in the fresh air as soon as he reached the surface. Dr. Haldane at once informed his audience that this would be the worst possible advice to give to a man who was half poisoned with carbon monoxide, because while one was lying quite still he might breathe a large amount of air containing carbon monoxide and not be the worse for it, but if the same quantity were breathed while one was undergoing active exercise the gas produced a distinct effect. Dr. Haldane advised that carbon monoxide gas should be removed from the blood by breathing fresh air or preferably oxygen, but that the sufferer should meanwhile undergo no muscular exertion.

Undoubtedly this gas can be detected by the test commonly known as the flame-cap test. He (Dr. Clowes) had worked more especially with this test himself, and found that 0·20 per cent. of the gas gave a flame-cap of $\frac{1}{2}$ inch over the standard hydrogen flame. But, unfortunately, this flame-cap test would only be of use in the pit, when it was known that the other inflammable gas, fire-damp, which gives a cap undistinguishable from carbon monoxide, was absent. One could not rely, therefore, upon the measurement of the cap for detecting the proportion of carbon monoxide present, except under special conditions. There was this further difficulty—even when the proportion of carbon monoxide had been accurately measured, that this measurement was not in itself sufficient to define the danger which might arise in the atmosphere containing it. If a small proportion of carbon monoxide were present in fresh air, its action

would be very slight; but if the air had lost some of its oxygen, or had been charged with carbon dioxide, then this small proportion of carbon monoxide would produce a considerable effect. The effect depends therefore, not only on the proportion of carbon monoxide present, but on the composition of the atmosphere itself, and for this reason the mouse test must prove of special value as a practical test of safety.

It was, nevertheless, important to detect the proportion of carbon monoxide in air, and Dr. Haldane's special test was, he believed, the only test at present available for the purpose in the pit. Under the old method of testing with blood for carbon monoxide, the blood was used just as it was drawn. Dr. Haldane suggests weakening the blood, before it is employed for testing for carbonic oxide. The action of carbon monoxide on the blood is indicated by a change of colour of the blood. The change of colour could not be readily seen with the naked eye, if the blood was of full strength, but must be examined by means of optical apparatus. Dr. Haldane found that if the blood was diluted a hundred-fold, a change of colour was produced by carbon monoxide, which was easily visible to the naked eye.

Dr. Clowes then proceeded with his demonstration, going through the process as recommended by Dr. Haldane. He used coal-gas, which contains a large proportion of carbon monoxide, for charging the diluted blood with the gas. The blood had been "whipped" to prevent it from coagulating (a process well known to slaughterers); it would keep for some time; and, if salted, might be stored for a week or a fortnight. Having introduced the blood into a bottle containing the gas, Dr. Clowes shook it up for 5 minutes. He then threw images of the freshly diluted blood, and of the same blood charged with the gas, upon a screen by means of a lantern, the blood being contained in narrow glass tubes for the purpose. The blood containing carbon monoxide appeared pink, while the fresh blood was pale reddish-brown in colour.

Dr. Clowes said that the process could be applied not only to the detection, but also to the measurement of the gas in the air. Dr. Haldane had carried out a series of measurements by this process, with a view to determining what amount of carbon monoxide in the air had caused death, in cases where men or horses had been poisoned underground by that gas. The examination might be made after a long period, since the blood held carbon monoxide, when it had once absorbed it, with extraordinary pertinacity; it might be kept for several months without losing the colour, which was imparted to it by the carbon monoxide. Dr. Haldane had sent him a sample of blood drawn from a horse killed underground by carbon

monoxide; the sample had miscarried, and was not received for six weeks, and was then becoming putrid. The experiment just described was, however, made, and the carbon monoxide colour was most strikingly evident. It was possible to draw blood from one's veins for this test, and Dr. Haldane had done so to himself. He had pricked his thumb, squeezed out a drop of blood, washed it off with a suitable quantity of water, and then made the test with this liquid. In conclusion, Dr. Clowes said he should like to hear opinions as to the practicability of applying this test in the form recommended by Dr. Haldane, and of making use of it as a means of preventing some of the serious consequences arising from breathing carbon monoxide.

Mr. A. H. STOKES (Derby) expressed his admiration of and thanks to such gentlemen as Dr. Haldane and Dr. Clowes for the manner in which they had conducted their investigations. As regards the demonstration which the members had seen that day, he should say that practically it was of little value, but scientifically of the greatest value. No one would think of making the blood test first, and rescuing the fallen afterwards. What mining engineers wanted was something to denote the kind of atmosphere into which they were advancing, because everyone knew who had had to deal with colliery explosions that a manager was suddenly called upon to act, under the most difficult and dangerous circumstances, and frequently to decide on the spur of the moment. He had to remember that not only the rescue of lives was in front of him, but that he was also charged with the care of a number of lives that went with him as an exploring party. Hence it was that a test which could be used immediately was wanted. He was aware of the mouse test, but that was a little unsatisfactory, as they could not wait to catch mice, unless mice were kept on the ground ready. He had seen the change of colour in the blood mentioned by Dr. Haldane, and up to a short time ago, it was not known by many—certainly not by himself—that the change of colour was due to the presence of carbon monoxide.

Mr. CHARLES LATHAM (Nottingham) said that at a previous meeting remarks had fallen from certain members with regard to the dangers of taking charged cylinders of compressed oxygen into the mine. In 1895 a Royal Commission* was appointed to enquire into the manufacture of compressed gas-cylinders, and after a most exhaustive enquiry the commissioners came to the conclusion that, provided the cylinders were made

* Committee appointed to enquire into the causes of the explosion, and the precautions required to ensure the safety of cylinders of compressed gas.

of good material, properly manufactured, and kept in good working order, there was absolutely no danger. In summing up their report they made a number of recommendations, which he had placed under the following heads:—(1) That the material of which cylinders were constructed should have a certain definite composition; (2) that the cylinders should be thoroughly tested and stamped with a date mark, and the testing should be repeated every two years; (3) that the cylinders should be annealed when new, and re-annealed every four years (no doubt some members might take exception to this recommendation, but they must not forget that there were certain other colliery-appliances which had to be annealed from time to time, so that the trouble would be very little extra); (4) cylinders for hydrogen and coal-gas should have left-handed connexions, and be painted red. The commissioners concluded by saying that, subject to a reasonable guarantee being obtained that these conditions had been complied with, they were of opinion that the cylinders might with safety be sent by road or rail unpacked. With regard to the danger of these cylinders exploding, it was true that some had exploded, but in every such case the cylinder had been a bad one. Some three years ago, Prof. Goodman made a number of experiments with fully-charged cylinders. They were dropped from heights of 25 to 50 feet on to a cast-iron block; and in every case the only result obtained was that the cylinders were slightly dented, but there was no fracture, much less explosion. Another interesting point had been raised as to the size of the cylinders. He had received a letter from Dr. Haldane, in answer to a question as to what amount of oxygen would be required to restore a man who was suffering from the effects of carbon monoxide. Dr. Haldane said that "the quantity of oxygen required to get rid of enough carbon monoxide from the blood of a poisoned man to enable him to walk when breathing air would vary according to the amount of carbon monoxide absorbed. But for an average quantity, he should think that about 2 feet, or say 10 minutes' breathing, would be about the right quantity. A few breaths would probably restore consciousness, but much more would be necessary to clear out the blood sufficiently to enable the man to walk."

He then exhibited a small portable cylinder, which might easily be slung over the shoulder, capable of holding about 4 cubic feet of oxygen—enough, by Dr. Haldane's calculation, to restore two men. If every explorer were provided with one of these cylinders, he thought that it might be the means of saving many valuable lives.

Dr. CLOWES said that he was constantly using steel cylinders; and there was not the slightest danger attending their use, provided they were made by a respectable firm. The railway companies had had in the past to deal with bad cylinders, and they would not relax their precautions just at present; but there was no doubt that, at some period not very remote, these regulations, which were unnecessary under present conditions, or, at any rate, much too stringent, would be modified. He (Dr. Clowes) wished to remind the members that there were certainly cases where the air of a particular part of the mine might be tested in a leisurely fashion aboveground by the blood-test, before men were allowed to remain at work in it. Undoubtedly it would be difficult to restrain men from entering air which might contain carbon monoxide in order to rescue others in case of emergency, but it was just in such cases that the mouse-test might be of value, and that small oxygen cylinders might be carried as restoratives both to rescuers and rescued. It should be remembered that when a man had fallen upon the ground, and his active exertions ceased, he was undergoing only a very slow process of poisoning as compared with the actively moving exploring party; he might lie there long in the foul air and still be restored. A few pet white mice, kept in a cage in the engine house, would solve Mr. Stokes' difficulties on that score; and a few duplicate oxygen cylinders, for use during the recharging of empty ones at the oxygen works, would remove the other objections.

Mr. A. H. STOKES said that although small cylinders were stronger and at the same time lighter in weight compared with large ones, still, if a number of small cylinders were kept for use at a colliery, large cylinders would be necessary for the purpose of re-filling them. The question was, how many of these cylinders would be required? For an exploring party, each man would want one for himself and another for the restoration of fallen men; but, if the atmosphere was so bad that explorers required cylinders of oxygen to enable them to penetrate it, how could the fallen men live till the explorers reached them?

DISCUSSION UPON MR. ALFRED SIERSCH'S PAPER ON "PHOTOGRAPHY IN THE TECHNOLOGY OF EXPLOSIVES."*

Mr. L. W. DE GRAVE (Derby) referring to the illustrations accompanying Mr. Siersch's paper, and more especially to those showing bright patches, Figs. 24 and 25, wrote that he had previously suggested that

* *Trans. Fed. Inst.*, vol. xi., page 2; vol. xii., page 574.

these bright patches might be caused by reflected light from the inside of the camera. This suggestion he had in a great measure confirmed by experiment. Further experiments, with both single and double flashes, copying Mr. Siersch's method in every respect, excepting the lens (which was a 3 inches focus working at $f/4$), gave patchy effects, which led him to the opinion that they were caused by the light from the flash being reflected from the polished woodwork and brass on the outside of the apparatus on to the glass shield and from that back into the camera. When the apparatus was covered up with a black cloth the effect was not obtained. The effects shown in Figs. 6, 7, and 23 he now attributed to light reflected from the products of detonation, and not from the secondary explosions or impact of molecules, although the former with some explosives was a distinct possibility, and he believed that in the case of carbonite there was evidence of serious accidents having occurred from the secondary explosions. The appearance of Figs. 24 and 25 was not such as to strengthen an opinion as to a secondary explosion, the effect of which would be much more blurred.

DISCUSSION UPON MR. R. F. PERCY'S PAPERS ON "THE DETERMINATION OF, AND USE OF THE MAGNETIC MERIDIAN IN MINE-SURVEYING" AND "AN IMPROVED PROTRACTOR."*

The PRESIDENT said that it was very important that the plans at collieries should be properly kept and should show the exact position of the workings in relation to the surface.

Mr. A. H. STOKES said that, owing to the latest Mines Regulation Act, it was now necessary to certify that plans were accurate and made by a competent draughtsman. He remembered some thirty years ago being in a serious difficulty with the plans of a colliery, where the workings were approaching water at a pressure of 200 lbs. per square inch, and after considerable trouble he found that the magnetic meridian had never been altered since 1848. In his later days of surveying he always put the true meridian upon the plan, and worked from it after obtaining the variation of the dial used.

Mr. C. R. HEWITT (Derby) remarked that in his district, surveyors were compelled to rely upon the magnetic meridian to a great extent in determining the relation of the underground workings to the surface. As

* *Trans. Fed. Inst.*, vol. xii., pages 581 and 585.

it was now customary to sink one pair of shafts only, seldom more than 132 feet apart, to work an area of 3,000 to 4,000 acres of mineral, there were many practical difficulties in fixing an underground base, and that being so, it was most essential that every care should be exercised in ascertaining the magnetic meridian. Mr. Percy's plan was one he had tried several times and he had found it very reliable, and if that method was applied, not only on one line, but on several lines in different parts of the estate, he did not think that anyone would get very far wrong.

Mr. H. B. HEWITT said that he disagreed with Mr. Percy in the last paragraph of his first paper, because he (Mr. Hewitt) thought that a meridian should be taken every twelve months at least, but preferably every six months, even assuming that every possible care was taken. It was not possible to have an accurate plan if the meridian was altered haphazard at every survey, to coincide with a supposed alteration of the true meridian.

Mr. ALFRED CHAMBERS thought that it was very desirable for young surveyors to test for themselves the actual magnetic meridian from points on the surface once a year. The true meridian should be delineated on the finished plan. The taking of bearings would be facilitated by an iron rod being fixed in the head-gear, a few feet above the pulleys, and vertically in line with the centre of the shaft.

Mr. C. J. OLIVER said that whilst agreeing with the author of the paper as to the necessity of great care in fixing the meridian line on the surface, he would like to know how it was proposed to transfer the line to the underground workings with equal exactness. Did Mr. Percy rely on the needle of the dial below ground? Where two shafts were available, surveying from one to the other, both on the surface and underground, appeared to offer the greatest advantages. He would also like to hear some further remarks on the contraction of paper. He remembered a case where the paper on which some base-lines had been carefully plotted, about 6 feet long, was altered so much in the course of a few weeks as to necessitate the whole being replotted.

Mr. W. F. HOWARD observed that his experience showed it was not enough to rely upon a scale drawn upon one part of the plan, because paper did not contract equally in all directions. He thought that the most practical and best test was to draw parallel lines at intervals of say 10 inches, crossed by other parallel lines at right angles, and so dividing the whole of the paper into squares before putting any other work upon it, thus providing scales directly applicable to every part of the plan.

This system he carried out as recorded in a paper contributed by him to this Institution in 1878.* He thought that Mr. Percy's suggestion for fixing the magnetic meridian from several connected observations was very good ; but at the same time he felt sure that the theodolite would have to be employed for the main surveys of extensive workings, leaving, however, the magnetic compass for the filling in of detail. Mr. Percy's protractor was ingenious, but still he should himself prefer to use the ordinary cardboard protractor, the accurate placing of which upon the plan was provided for by the system of squares previously drawn upon the paper, of course with proper adjustment to date and observation.

Mr. R. F. PERCY (Nottingham) said that the President had mentioned a number of points reminding the members of the extreme importance of ensuring the correctness of mining plans. Yet surveying was frequently entrusted to young men who did not appreciate the responsibilities of the office, but who merely regarded the appointment as a stepping-stone to some better position, reliability and preciseness being often sacrificed in the interest of economy of labour. The importance of the meridian merited the devotion of more time to its determination than was generally given. Some surveyors took a meridian at each quarterly survey by the simple process of a single observation on the surface, after a day's work in the mine. It was better to leave the meridian on the plan alone until a whole day could be spared for the work, and then the observations should be made in every locality beneath which the coal was being worked, and every observation should be proved by a method such as he had explained in his paper, or some other equally efficient. He did not think that there was much advantage in showing the true or geographical meridian on the plan. It would be of the greatest service if there were some simple means of ascertaining the declination of the needle ; but, unfortunately, there was not. The geographical meridian, to be of actual service, should be staked out on the surface ; and then the stakes would be of no more use than any other field-points which happened to be indicated on the plan. It would be a great mistake to rely on the magnetic reading of a single line, even if that should happen to run due north and south.

The PRESIDENT, in moving a vote of thanks to Mr. Percy for his papers, said that it would be to the advantage of many coal-owners if more attention was paid to the surveying.

* *Trans. Chem. Inst.*, vol. v., page 315.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND
MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT,
MARCH 8TH, 1897.

MR. JOEL SETTLE, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected :—

MEMBER—

Mr. GEO. A. MILLWARD, Shelton Iron, Steel, and Coal Company, Limited,
Stoke-upon-Trent.

STUDENTS—

Mr. CHALKLEY VIVIAN GOULD, Rosedale, Alsager.
Mr. PERCY TURNER, 4, Ashwood Terrace, Longton.

THE KENT COAL-FIELD.

Mr. C. E. DE RANCE said that the South Eastern railway was carried from Folkestone by the side of East Wear Bay, and thence through tunnels at Abbot's Cliff and Shakespeare Cliff to Dover. The Chalk and underlying strata dipped towards the north-east, and the cliffs consisted of Chalk, which except near the base, was nearly dry. Below them, the railway traversed the "Little Switzerland district," so named from the beauty of its scenery, which was largely due to the broken ground caused by landslips, separated by cracks and fissures of a very remarkable character, and changing their aspect from year to year. These changes were produced by springs in the Gault Clay, lying immediately below the Chalk, which was impervious. These springs caused the cliffs to be more or less in continual motion. The water, in the sands known as the Folkestone and Sandgate Beds, caused a few years ago at Sandgate a difficulty in keeping the town on a sure foundation. Houses were cracked, water-pipes were disturbed, and the embankment suffered great damage.

The shaft, near Dover, in which the men were working, was said (in the daily newspapers) to be 300 feet deep ; and in that relation it was interesting to read the detailed section of the strata of the boring made at the point in question.* The horizon of the junction of the Folkestone and Sandgate Beds, at a depth of 303 feet, was probably the horizon from which the water broke into the shaft. Trial-borings had been made in advance at the bottom of the shaft, which suddenly moved upwards. It appeared to him that, where artesian water was likely to be found, test-borings should be made to some depth, and that gauges should be used to ascertain the pressure of the water in the bore-holes.

DISCUSSION ON THE "EXPLOSIVES IN COAL-MINES ORDER, 1896."†

The PRESIDENT directed attention to the Explosives in Coal-mines Order made by the Secretary of State for the Home Department under Section 6 of the Coal Mines Regulation Act, 1896, which would come into force on July 1st, 1897. An important matter was that not more than 10 men must be in a mine when a shot was fired in a main haulage-road, unless the mine was naturally wet. He did not take exception to the order as far as deep mines were concerned, but in upper seams it would be found to work very disadvantageously. Although the order might seem to be hard on those who were working the upper seams in that district, he thought that it would in time be found to be an advantage, because it would increase the cost in districts where powder was used to a greater extent than in North Staffordshire.

Mr. J. J. PREST said that at the Shelton collieries they were probably using a larger quantity of the permitted explosives at the present time than any other colliery in the district, and he could therefore claim to speak with some knowledge of the subject. He was entirely in favour of the abolition of blasting-powder in all dry and dusty coal-mines, but he certainly was not in favour of the Explosives in Coal-mines Order, and he thought that an endeavour should be made to obtain such a modification of its terms as would make it a practical measure. For instance, by section 3, it would be necessary to remove all persons out of the seam except 10 if a shot was to be fired at the face of a main intake-airway for the purpose of extending or driving the place—as he assumed that the face was as much a part of the main intake-airway as any other portion

* *Trans. Fed. Inst.*, vol. xi., pages 542 and 544. † *Ibid.*, vol. xiii., page 18.

of the road. Manifestly this compulsory withdrawal of workmen was an unnecessary hardship, and one that should be remedied. Then, again, the first part of section 4 excluded mines of stratified ironstone from the operations of the order, but the second portion of the same clause said that "Where a mine contains several separate seams, this order shall apply to each seam as if it were a separate mine: provided that several seams communicating with the shaft at the same level shall be deemed to be one seam"—so that a colliery working several distinct seams of coal and ironstone, all communicating with the shaft at one level, would have to use the same explosive for getting the ironstone as was used for getting the coal. On the whole, he should have been pleased if the order had simply prohibited the use of blasting-powder in dry and dusty coal-mines.

Mr. G. A. MITCHESON said it had been asserted that the effect of the order would be to close many collieries in different parts of the country, owing to the increased cost of using high explosives as compared with powder. He took exception to this statement, as he did not think that the difference in cost between the two classes of explosives would be material, but he could quite understand that there would be an increase of cost at those collieries where the shot-lighting had been done by the ordinary collier, as it would now have to be done by an official. He was of opinion that the order would prove advantageous to North Staffordshire, as almost without exception shot-firing was being carried out in North Staffordshire at the present time in the way required by the order, and consequently other districts would now be placed on the same footing. He thought no one in this district would like to go back to the old practice of allowing ordinary colliers to fire shots.

Mr. E. B. WAIN thought that section 4 meant that a seam of ironstone worked in the same pit was a distinct seam, although it might be collected to the same level as the coal. Years ago, any collier was allowed to fire a shot; if it cost a little more to have properly qualified firemen they got the benefit in not having so much slack coal. It was possible that the prohibition of the use of gunpowder might work some good to North Staffordshire. The fact that an explosive was more costly would tend to restrict its use. If the coal was properly holed and dressed, instead of being violently shattered by the action of the explosive, the extra cost would be more than repaid by the increased value of the coal. The first section of the order prohibited the use of certain explosives in all cases where there was inflammable gas, but there was no definition of what

inflammable gas might be, and it would be unfair to condemn as unsafe a mine where a minute quantity of fire-damp was found on a single occasion. In sub-section *b* of section 2, it was stated that "the apparatus or method, whether electrical or otherwise, used to ignite the charge in the firing of any shot shall, so far as is reasonably practicable, be incapable of igniting inflammable gas or coal-dust." The words "so far as reasonably practicable" ought not to appear in such an order. The Home Secretary should not leave it to a colliery manager to say whether an apparatus was or was not incapable of igniting inflammable gas, but having satisfied himself that certain methods were safe, he should have included them in the order as "permitted," in the same manner as he had "permitted" certain explosives.

Mr. GREGORY said that if danger resulted from firing a shot in a coal-seam the men in an ironstone-seam would stand the same risk if that seam were on the same level as the coal.

Mr. W. N. ATKINSON said that the permitted explosives were mentioned in the order, and no application to use them would be necessary. He did not consider that a breasting formed a part of a main intake airway, and the order would not stop blasting at a breasting, although it was the face of an intake-airway. Then as to ironstone, he was not prepared to say whether Mr. Prest's view was the correct one with reference to the intention of the words—"that several seams communicating with the shaft at the same level shall be deemed to be one seam," further than that then when shots were fired in the main intake-airway, the men would have to be withdrawn from the ironstone as well as from the coal-seam. The words "reasonably practicable," in the clause relating to the method of firing shots were intended to avoid laying down a rule that would prevent the adoption of any new and improved method. Although he had no authority for saying that the Secretary of State would alter the order, he was quite sure if it could be shown that it could be improved and still maintain the same standard of safety, there would be no disposition to adhere to it as if it were one of the laws of the Medes and Persians, which could not be altered.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND
MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT,
MAY 10TH, 1897.

MR. EDWARD B. WAIN, PAST-PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

DISCUSSION ON MR. HARGRAVE WALTERS' PAPER ON
"LEAD AND LAP OF WINDING AND OTHER ENGINES."*

Mr. BENJ. WOODWORTH (Fenton) wrote that the arrangements described in this paper could be best characterized as an ingenious device to provide some remedy for a state of things which ought not to be allowed to exist under any circumstances, and which could be better remedied in a simpler manner that would give more satisfactory results as to efficiency, economy, or durability. It is astonishing how tenaciously the old idea is adhered to that a winding-engine must have steam admission for practically the full length of its stroke. As the inevitable result of such working a considerable percentage of the useful effect of the steam is wasted in forcing out the exhaust steam; and with high speeds the waste from this cause often becomes of alarming proportions. No winding-engine, however heavily laden, needs to have a steam admission exceeding 90 per cent. of the stroke, and with moderate loading the main valves may be arranged for a cut-off as early as 75 per cent. without incurring any difficulties of starting or landing. When further steps in economy are taken, an expansion-gear should be adopted that can proportion itself to the work required (and what is often most important) that it shall come into operation as early as possible in the winding instead of being brought into action by governors, after anything from 30 to 70 per cent. of the whole work required has been already done in full gear. To bring governor arrangements of cut-off gear into action at earlier stages it is necessary to put down more powerful engines than are needed for first-class working, and often it follows that the expansion of the steam in

* *Trans. Fed. Inst.*, vol. xi., pages 64 and 233.

such cases is carried much below the useful limit of work, producing a reaction that partially neutralizes all the other benefits accruing.

Mr. W. G. COWLISHAW wrote that, if he understood Mr. H. Walters aright, he proposed by means of a combination of levers, etc., to be able to alter the position of the eccentrics on the shaft, the effect of this being to alter the position of the slide-valve with relation to the piston, when the engine is either running or standing. In his opinion, such an arrangement would do more harm than good, when applied to a winding-engine, his main objections being as under : (1) The placing of the gear under the control of the engineman was distinctly wrong, as it would be but rarely used, and then perhaps at the wrong time. He noted that Mr. H. Walters spoke of making the gear automatic, but probably he would find the cost at least doubled, and the wear-and-tear of the working parts quadrupled. (2) He considered that the arrangement as illustrated in the *Transactions* would be subject to a great deal of wear-and-tear, and he would be inclined to say that much of the benefit claimed by Mr. Walters would be discounted by loose joints in a short time. (3) The strongest objection is not so much to the manner of carrying out the arrangement, but to the proposal itself. Let us follow a cycle of events : A few revolutions of a winding are made, when the gear is thrown into operation, the working eccentric being advanced, taking with it of course the slide-valve. This would mean (a) steam admission earlier, causing an undue amount of compression, and so actually retarding the speed of the engine ; (b) steam cut-off earlier, which is desirable ; (c) exhaust opening earlier, and therefore much of the benefit gained by the earlier cut-off and expansion of steam is lost ; and (d) exhaust closing earlier, resulting again in compression and retardation of speed of engine. To be of any practical value, it should be possible to cut-off with this gear, at least one-quarter of the stroke earlier than with a valve under ordinary conditions, and as a maximum, one-half stroke earlier. What sort of a diagram would be produced, with the whole cycle of operations advanced 90 degrees ? The exhaust slide of a valve when once set right for the load and running should not be interfered with. Consequently, the only proper method of varying the admission of steam is by separate valves or cut-off plates at the back of the slide-valve. The linking up of a locomotive is not analogous in action to this gear, as linking up merely reduces the travel of valve, and it does not alter the relative positions of piston and slide-valve. In his opinion, this gear is wrong in principle, and he could not conceive of a case where its application would be an unmixed advantage.

Mr. J. J. PREST said that when this paper was last under discussion Mr. T. M. Favell put the case for a variable lead in a nutshell when he stated that for slow-running engines lead was not wanted, and for quick-running engines a very considerable amount of lead was necessary. Hence he assumed the reason why Messrs. Thornley and Walters had designed the arrangement for overcoming this difficulty; and, to his mind, they seemed to have done so in a very simple and efficient manner. The movable eccentric was designed for ordinary high-pressure engines fitted with slide-valves, working intermittently at various piston speeds, and where there was sufficient space in the valve-box to allow of variable lead being given the arrangement would no doubt effect considerable economy in the consumption of steam, particularly so with engines hauling long distances or winding from considerable depths. He entirely agreed with Mr. Walters that the same result could not be obtained by an ordinary expansion-valve. It would have been interesting to many engineers if Mr. Walters could have given diagrams of a complete wind, with fixed and with variable lead. The advantages of the devices would have then been more apparent. On the subject of Cornish *versus* balanced slide-valves, he was strongly of opinion that the latter are the most economical for winding-engines of any size. The pins, tappets, and lifters of Cornish valve-gear required constant renewal and repair after being in use for a few years; it was difficult to keep the valves tight, and leakages of steam were of frequent occurrence in consequence. Recently, owing to these causes, he had replaced the Cornish valves on a large horizontal winding-engine with balanced slide-valves, and it was now winding 3 tons of coal from a depth of 1,590 feet in the same time and with the same consumption of steam as it formerly used when winding 32 cwts. of coal from the same depth.

Mr. HARGRAVE WALTERS (Birley Colliery) wrote that Mr. Woodworth could hardly have had the paper before him, as it distinctly stated that the arrangement was to be used for giving lead, at will, while an engine was running. Mr. Woodworth's remarks especially applied to expansion gear cut-off, which he also strongly advocated; but Mr. Woodworth overlooked the combined advantages which suitable variable lead would give. Mr. Cowlshaw is mistaken in stating that the gear is a combination of levers, as the gearing is most simple and conspicuously free from objections, and is made to work automatically. Mr. Prest stated the advantages of the gearing exactly, as it was obvious that variable lead could not be obtained in so direct a manner as by actually moving the eccentrics.

DISCUSSION UPON MR. C. E. DE RANCE'S "NOTES ON WATER SUPPLY."*

MR. C. E. DE RANCE said that since he read his paper he had spent nearly a month in the House of Commons in committee on the Newark and Nottingham Corporations' Water Bills. During that time he had heard the expressions of opinions of nearly every water expert in the country, and he was glad to state that after this useful and interesting experience he had nothing to alter or modify in the paper which he had the honour to lay before the Institute, which embodied the results of his own practical experience of the past 30 years, his own observations in that paper commencing in 1867.

Mr. de Rance exhibited various diagrams and sections. The first showed the comparative results of rainfall, at different periods of the years, as regards resulting percolation of water into the ground between 1863 and 1866 in the Colne valley north-west of London. In 1863-4, a rainfall from October to March of 9·24 inches gave 5·9 inches of percolation, while a rainfall of 8·42 inches from April to September only yielded 0·45 of an inch; 12·6 inches of rain in April to September, 1865, gave no percolation whatever; but 20 inches falling between 1865 and March, 1866, yielded no less than 12 inches of percolation; on the other hand, 15·6 inches falling in April to September, 1866, yielded only 0·2 inch of percolation.

Diagrams of the Colne Valley, Hertfordshire, and the Darent Valley in Kent, showing seasonal variations of the saturation-plane, and its rough conformity to the surface-undulations of the ground overhead were exhibited, also a series of sections, showing the variation according to season, of Chalk waters drawn to scale, in Kent, Surrey, Middlesex, Herts., Norfolk, Lincolnshire, and Yorkshire, prepared, measured and drawn by Mr. Edward Easton, C.E., for the Royal Commission on London Water Supply, the general results of which went to prove the contention in his (Mr. de Rance's) paper, that enormous volumes of water passed under impermeable strata to the sea and were lost for effective use for trade or potable purposes. Mr. Easton informed him that not only did freshwater springs bubble up in great force off St. Margaret's Bay, near Dover, on the Kentish coast, but the fishermen on these sites actually caught freshwater eels in their nets.

* *Trans. Fed. Inst.*, vol. xii., page 598.

CHESHIRE SALT DISTRICT.

Mr. C. E. DE RANCE exhibited several vertical sections published by the Geological Survey, including two of the latest issued, sheet 82, drawn up and compiled by himself, of the Cheshire salt district, the sections being arranged geographically in relation to one another, and plotted to ordnance datum, the varying heights of the columns representing the different levels of the surface above that datum. An inspection of this plate showed that the character, thickness, and other details of the salt-beds differ in each individual section. That the true rock-head brine flowing on the surface of the uppermost bed of rock-salt at Winsford and Northwich, was really an artesian water at pressure, impregnated with 2 pounds 11 ounces of chloride of sodium when fully saturated. This supply was in no way connected with the enormous quantity of brine pumped at Northwich by Messrs. Brunner, Mond, & Co., and the Salt Union, Limited, from brine ponded up in the bottom of old mines, made in the lower 20 or 30 feet of the lowest bed of rock-salt, to which access from the streams was afforded by means of the deserted subsiding shafts. This access is not continuous, but periodic, and is accompanied with sudden rises of weak muddy brine and water in the shafts, which always rise to a level a little below that of the river Weaver, the height of the column being controlled by the difference of the specific gravity of brine at the base, and that of the fresh water at the top.

SOUTH WALES AND LANCASHIRE COAL-FIELDS.

Mr. C. E. DE RANCE exhibited sheet 81 of the vertical sections of the Geological Survey of the steam coal series of Glamorganshire and Monmouth, drawn up very recently by Messrs. Strahan and Gibson, which, unlike most of the Survey sections, is drawn on the scale of 100 feet to the inch, instead of the usual 40 feet to the inch. Mr. de Rance pointed out that in 1876 he designed and collected the material for sheet 61 of the vertical sections of the Survey, which was the first one published on the 100 feet scale, and arranged geographically, and plotted upwards from the Arley mine, as a natural base to the Lancashire coal-field, which established two very important facts: (1) That the basin was one of contemporaneous subsidence, the measures thickening 66 feet per mile to the centre, while the coals thicken to the margins of the basin; and (2), that this explains the difference of vertical thickness between two given coal-seams, on opposite sides of a fault, at the same or an adjacent colliery, the fault, though of limited vertical displacement, having moved the area bodily a mile or more horizontally and brought the thick end of the wedge against the thin end.

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION
OF ENGINEERS

AND
MIDLAND INSTITUTE OF MINING, CIVIL, AND
MECHANICAL ENGINEERS.

JOINT MEETING,

HELD IN THE ROOMS OF THE LITERARY AND PHILOSOPHICAL SOCIETY,
SHEFFIELD, JANUARY 23RD, 1897.

MR. M. H. MILLS, IN THE CHAIR.

Mr. G. BLAKE WALKER read the following paper on "Recent Progress in the Recovery of Bye-products from Coke-ovens in Westphalia," by Messrs. G. Blake Walker and L. T. O'Shea:—

RECENT PROGRESS IN THE RECOVERY OF BYE-PRODUCTS
FROM COKE-OVENS.

BY GEORGE BLAKE WALKER AND L. T. O'SHEA.

No subject is of greater interest to mining engineers at the present moment than the improvements which have recently been made in the construction of coke-ovens, with the object of obtaining and saving the volatile constituents of the coal which, under the system of coking in beehive coke-ovens usual in this country, are now allowed to burn away to waste. The flame and smoke which issue from coke-ovens contain substances of nearly equal value to that of the coke, and if they can be obtained without injuring the quality of the coke, the value of the small coal sent to the ovens may be about doubled.

The writers visited Westphalia last summer, and although the special object of their journey was not connected with the manufacture of coke, they were very much struck by, and interested in, the exceedingly important developments which had taken place in that industry in Westphalia during the last few years.

The subject of the recovery of the bye-products of coke-ovens is the one in which German mining engineers are at present chiefly interested, and although alterations and improvements are taking place almost from day to day in working out this important problem, its present position is worthy of the close attention of the members of the Institute.

The writers do not claim to have special knowledge of the subject,

and have offered their notes because they think that it may be a convenience to the members to have the subject brought before them at the present time in order to give an opportunity for discussion, and to draw attention to the fact that the problem of the recovery of bye-products from coke-ovens has been successfully solved, rather than to advocate the merits of any particular system of coke-oven. They do not forget the fact that the whole question of coking highly bituminous coals in retort-ovens as opposed to beehive coke-ovens was thoroughly considered by the most competent authorities, such as Sir Isaac Lowthian Bell, Mr. A. L. Steavenson, and others, many years ago, and that the conclusion arrived at was, that on the whole the greater yield of coke made in retort-ovens did not compensate for its inferior appearance and unsuitability for metallurgical purposes, and that for the time being beehive coke-ovens held the field. It must be admitted, however, that much has happened during the last ten years, and the additional value obtained from the coal when the bye-products are recovered, now throws the balance of advantage very largely on the other side.

Papers were recently read before the North of England Institute of Mining and Mechanical Engineers on two of the most recent types of coke-oven for recovering the bye-products—viz., the Semet-Solvay,* and the Brunck,† but curiously the Otto-Hoffmann oven, the most celebrated of all, and the most widely used in Germany, had not yet been the subject of a paper.

Since the introduction of the Otto-Hoffmann oven with recovery of bye-products, the development of the coke industry in Germany, and especially in Westphalia, has been extraordinary. The output of coke in the Dortmund district is stated to have been as follows during the ten years from 1885 to 1894‡ :—

TABLE I.—COKE PRODUCTION.

Year.			Tons.		Per Cent.
1885	...	...	2,826,697	...	—
1886	...	...	2,557,013	...	decrease 11·00
1887	...	...	3,143,922	...	increase 23·00
1888	...	...	3,592,990	...	„ 14·00
1889	...	...	3,813,027	...	„ 6·00
1890	...	...	4,187,780	...	„ 9·80
1891	...	...	4,388,010	...	„ 4·77
1892	...	...	4,560,984	...	„ 4·00
1893	...	...	4,780,489	...	„ 4·80
1894	...	...	5,398,612	...	„ 12·93

* *Trans. Fed. Inst.*, vol. ix., page 54. † *Ibid.*, vol. ix., page 47.

‡ "Die Fortschritte der Koksfabrication im Oberbergamtsbezirk Dortmund in den letzten 10 Jahren." By Mr. F. Simmerbach. *Zeitschrift für das Berg-, Hütten- und Salinen-Wesen im Preussischen Staate*, 1893, vol. xlv., page 402, and plates.

During the last two years, 1895 and 1896, this rapid increase has been fully maintained, and there are probably now nearly 10,000 coke-ovens at work or erecting in Westphalia.

Notwithstanding this remarkable development of the coke-making industry in Westphalia, and the large measure of success which had been attained in the recovery of the bye-products, finality had not yet been reached. The behaviour of a particular coal in a given coke-oven cannot be predicated with absolute certainty, and the best type of oven for one coal may be quite unsatisfactory for another. Recognizing this fact, the Simon-Carves Syndicate in Great Britain and the firm of Dr. C. Otto & Co., of Dahlhausen, have decided to erect a number of experimental ovens of various kinds, and to make experiments in these ovens with all sorts of coal, with the object of determining which system can be regarded as giving the best results with coals of a particular composition. These experiments may be expected to throw a good deal of light on a subject as to which science has still much to learn.

In Westphalia, in 1895, there had been a decrease in the number of types of ovens in use as compared with 1885. Of the 6,464 ovens in use in that year, only 306 were bye-product ovens, only 3,700 were utilized in connexion with heating boilers, and most of the ovens themselves were quite obsolete or disused. Ten years later, there were 7,866 ovens in use, of these only 142 were beehives and 1,864 were bye-product ovens. These were at the end of 1895, divided between the different systems, as follows, but a considerable increase in some of the newer types has taken place during the past year :—

				In 1895. Ovens.	In 1896. Ovens.
At Collieries—					
Otto-Hoffmann	...	...	...	1,102	1,722
Hüssener	...	...	...	100	100
Herbertz	...	...	...	48	48
Ruppert	...	...	...	140	140
Ruppert-Collin	...	...	...	60	60
Collin	...	...	...	60	260
Brunck	...	...	...	66	186
At Iron-works—					
Otto-Hoffmann	...	...	...	160	320
Brunck	...	...	...	—	60
Totals	...	...	...	1,736	2,896

It may be convenient to divide the subject of this paper into :
 (1) A few general remarks on the chemical action involved in the coking of coal ; (2) a brief account of the evolution of the bye-product oven, and a description of the condensation-plant, by means of which the tar and ammonia-liquor are obtained from the coke-oven gases ; and
 (8) general conclusions.

THE CHEMISTRY OF COKE MANUFACTURE.

It may seem superfluous to introduce into this paper an account of the chemical action which goes on in the coke-oven, so far as this is at present understood ; but as this information is only to be obtained from highly technical sources, we have thought it may be a convenience to many members to have a succinct account of the process.

The action of heat on coal is to bring about its decomposition, the chief feature of which consists in the separation of the greater quantity of the hydrogen, oxygen, and nitrogen which the coal contains, in combination with one another and with carbon in the form of definite compounds, whilst a considerable proportion of the latter is left as a non-volatile residue which constitutes the coke. Although all coals undergo this change on heating, different varieties of coals behave very differently under the action of heat. Some coals pass through a pasty condition, and give rise to a coherent mass of coke bearing no resemblance to the original form of the coal ; whilst others do not pass through this pasty condition, the coke is non-coherent, and each lump retains the form of the original coal. This property gives rise to the terms *caking* coals as applied to the former class, and *non-caking* coals to the latter.

Considerable attention has been given to the subject, with the object of determining on what the difference in behaviour of these two classes of coals depends, and many speculations of a more or less theoretical character as to the chemical changes that take place, have from time to time been made to account for this difference. It is not thought desirable to enter into this question in this paper, but reference may be made to the influence which the chemical composition of coal has on its caking properties—an influence which Dr. Regnault first attempted to elucidate. It has been suggested that the proportion between the amount of oxygen and hydrogen present has considerable influence in this respect.

The mean composition of different varieties of foreign coal is given in the following table * :—

TABLE II.—COMPOSITION OF FOREIGN COALS.

	Elementary Composition.			Molecular Ratio of Hydrogen to Oxygen.	Disposable Hydrogen.
	Carbon.	Hydrogen.	Oxygen.		
Sand coal... ..	77	5	18	4.54 : 1	2.54
Semi-bituminous or sinter coal ...	83	5	12	6.60 : 1	4.60
Caking coal ...	87	5	8	10.00 : 1	8.00
Anthracite ...	95	3	2	30.00 : 1	28.00

* *Chemical Technology, Fuel and its Applications.* By Messrs. E. J. Mills and F. J. Rowan.

From this table, it is seen that in the first three coals the amounts of hydrogen are identical, whilst the quantity of oxygen decreases, and consequently the molecular ratio of hydrogen to oxygen increases. The increase in this ratio is attended by an increase in the caking properties of the coal. In the case of anthracite, however, the ratio of hydrogen to oxygen is much greater than in the other cases, but the amounts of hydrogen and oxygen are very much smaller than in the first three coals. Now, every molecule of oxygen requires two molecules of hydrogen to form water, and the excess of hydrogen in the coal over that required to form water is called the "disposable hydrogen." It would appear, and has been held, that the caking properties depend partly on the amounts of hydrogen and oxygen present, and partly on the amount of disposable hydrogen. Although these facts doubtless have some influence, yet the caking properties cannot be entirely influenced by them, for Dr. Percy has shown that the amount of disposable hydrogen may be the same in caking and non-caking coals, and Prof. Stein, of Dresden, has shown that caking and non-caking coals may have the same elementary composition.

It will be seen, then, that the elementary chemical composition of coal does not help much to determine the caking character of a coal, and that whilst the disposable hydrogen doubtless has some influence in that direction, yet we must remember that coal is a highly complex body, with regard to whose molecular constitution we are absolutely ignorant. It is most probable that the caking properties depend on the presence of resinous bodies in some coals, whilst their absence in others deprives them of this property.*

THE COKING PROCESS.

When the process of coking is carried out in closed vessels, the volatile products may be collected, and the substances obtained by this distillation, whether primarily carried out for the manufacture of coal-gas or of coke, are as follows:—(1) coke; (2) tar (condensable volatile compounds); (3) ammonia; and (4) gases (uncondensable volatile compounds). It will be convenient to consider the chemical properties of each of these substances separately.

(1) *Coke*.—Coke is not pure carbon, but always contains small quantities of hydrogen, oxygen, nitrogen, and sulphur, together with the incombustible constituents of the coal used which constitute the ash.

* *Trans. Fed. Inst.*, vol. xii., page 465.

TABLE III.—ANALYSES OF COKE.*

Samples.	No. 1.	No. 2.	No. 3.
Carbon	89·85	87·60	86·36
Hydrogen	2·00	0·25	0·51
Oxygen and Nitrogen ... }	...	1·20	1·77
Sulphur	1·06	1·05	1·07
Ash	6·00	8·52	7·94
Water	0·49	1·36	2·35

The carbon and hydrogen are valuable constituents, whilst sulphur is most injurious.

Coke should be hard and porous, and these properties are influenced by the character of the coal and the conditions of manufacture. To obtain the best results in this respect, the coal must be brought to a thoroughly pasty condition, and the regular escape of gases allowed to take place. If the coal be too rich in volatile substances, the gases escape with violent ebullition, and a large proportion of breeze coke results, whereas coals containing less than 20 per cent. of volatile matter do not properly fuse. The temperature of production, according to Dr. Percy, affects the character of the coke, which in general may be said to be harder, denser, and less easily combustible the higher the temperature and the longer the duration of that temperature. It seems to the writers, however, that no absolute rule can be laid down, but that each variety of coal requires special conditions to produce the best results: these, in the present state of our knowledge, can only be determined experimentally.

The sulphur present in coke is a very injurious constituent, and it is always desirable that this should be as low as possible: in coke of first quality it should be under 1 per cent. Sulphur is derived from two sources:—(1) The impurities, such as iron pyrites and gypsum, which are always mechanically mixed with the coal, and (2) the sulphur which enters into the composition of all varieties of coal. The former source of this impurity can be removed from the coke before coking by the process of washing, but the latter cannot be so removed. On distillation, a portion of the sulphur escapes in the form of various compounds, but it never can be completely expelled, and although various inventions have been introduced for the purpose of reducing the amount of sulphur in coke, the only method in the writers' opinion that contains the elements of success is the treatment of coke whilst hot with steam

* *Chemical Technology, Fuel and its Applications.* By Messrs. E. J. Mills and F. J. Rowan.

(which was patented in 1858 by Messrs. Claridge and Roper) when sulphuretted hydrogen is formed. One drawback to this process is that sensible quantities of carbon and hydrogen are removed at the same time.

The ash is included in the weight of coke obtained. The ash is either fixed or loose. The loose ash may be removed by a process of washing, but the fixed ash will always remain; it is not, however, without its advantages, as a small percentage of ash usually adds to the mechanical strength of the coke.

The process of coking may be conducted either with or without the admission of air; in other words, it may either be burnt or distilled. The former is the process in the ordinary beehive coke-ovens chiefly used in Great Britain, the latter in the closed ovens used on the Continent. In the former case, by admitting a certain amount of air, and allowing the coal to flame until the whole mass is incandescent, the coal becomes fairly uniformly heated; in the other, the heat being communicated from flues in the sides and bottoms of the ovens, the coal lying close to the floors and bottoms of the ovens gets the greatest amount of heat. Thus, while large circular ovens are used where air is admitted, very narrow ovens are required where the coking is effected in a closed chamber.

It is important to bear in mind that in the latter case the coal lying next the walls and floor becomes coked first; and coke, being a poor conductor of heat, retards the passage of the heat to the central part of the charge. But the gases drawn off find a readier passage where the coking process is least complete: a sort of boiling process goes on in the centre, and at the top of the charge gas-bubbles are formed, and the coke tends to become porous and spongy.

These differences of density are roughly illustrated in Fig. 1 (Plate XVI.), in which the densest coke is that nearest to the sides and bottom of the oven, and the least dense in the centre. The width of the oven may vary from 1 foot 6 inches to 2 feet. It is sometimes argued that in the wider oven the actual amount of porous coke may be greater, but the proportion of it to the whole charge is not greater than in the narrow oven; but experience does not altogether support this contention.

Another foreign constituent of coke is moisture. Coke attracts moisture from the air, sometimes in considerable quantities. The tendency of coke to absorb moisture is the reason of the difference in the appearance of coke slaked inside from that cooled outside the oven. Coke slaked inside the oven has a silvery metallic appearance, which is much thought

of as an evidence of quality; but coke slaked outside is apt to be over-watered, and in any case loses much of the silvery appearance referred to.

The quantity of moisture in the coking coal is a factor which deserves careful consideration. According to a writer in *Stahl und Eisen*,* the heat required to evaporate the moisture is not only lost, but through the high percentage of moisture a diminution of the output of coke takes place through the oxidation of carbon. Gaseous coals, however, require to be put into the oven in a moist state (10 to 15 per cent. of water) if a good yield of coke is to be obtained without sacrificing the quality. If dry coal be put into the oven, a violent ebullition immediately takes place, the fine particles of coal are carried off by the draught, and spongy coke is produced; whereas if the coal be sufficiently wet, the ebullition of the gas is retarded, so that each part of the coal lies closer, and melts more uniformly, and better coke is thus produced. The violent ebullition at the commencement of the coking of a charge of very gaseous coal is due to the higher proportion of oxygen which these coals contain.

Where the oven-gases are drawn off by artificial suction (as in bye-product ovens), the use of dry, dusty coal is likely to give rise to obstructions in the pipes from the coagulation of the particles of dust. Bye-product ovens should, therefore, be supplied with coal containing from 10 to 15 per cent. of moisture.

The other products, tar, ammonia, and gas, go by the name of bye-products in the manufacture of coke. In the beehive coke-oven (where air is admitted) these are completely destroyed by combustion, but in several forms of closed ovens these are now collected.

(2) *Tar*.—This black, foetid-smelling liquid consists of a mixture of definite compounds of carbon, with hydrogen, oxygen, nitrogen, and sulphur. The compounds may be divided into the following groups:—

(A) Hydrocarbon compounds of hydrogen and carbon, of which two different classes are found in the tar:—(a) Fatty hydrocarbons, such as amylene, hexylene, etc., and (b) aromatic hydrocarbons, of which benzene, toluene, naphthalene, and anthracene are examples.

(B) Acids and phenols, containing carbon, hydrogen, and oxygen, of which the most important are phenol (carbolic acid), cresol, and certain tar acids.

(C) Bases containing carbon, hydrogen, and nitrogen, amongst which may be mentioned aniline, pyrrol, and chinolin. Lastly, certain neutral bodies are present.

* "Betrachtungen über den Verkokungsprocess," 1894, page 203.

The character of the tar, as well as the yield from any coal, depends on the temperature at which the distillation is carried out. The most valuable products are benzene, anthracene, and naphthalene, and it is found that if the distillation be conducted at about 800 degs. Fahr. the tar is lighter than water, and contains but small quantities of these bodies; but that between 1,700 degs. and 2,000 degs. Fahr. the tar becomes thicker, and, though smaller in quantity, is richer in these hydrocarbon compounds. A further increase in the temperature, however, tends to decrease their quantity, owing to the decomposition which they suffer under the influence of the high temperature. The admission of air into the closed oven during the coking process (as in the Jameson oven) affects the quality of the tar. Mr. Watson Smith stated* that the tar from this form of oven had a low specific gravity, and contained neither benzene, anthracene, or naphthalene; whereas the tar from the Simon-Carvès oven contained benzene, carbolic acid, naphthalene, and anthracene "in such quantities as place it on a level with the best tars of the London gas-works." To recover the different constituents of the tar, it is subjected to a process of fractional distillation, by which it is separated into the following portions, according to the temperature at which they distil over:—

(a) First runnings (105 degs. to 110 degs. Cent., or 221 degs. to 230 degs. Fahr.), which contain the most volatile constituents of the tar, together with appreciable quantities of benzene, carbolic acid, and naphthalene.

(b) Light oil (210 degs. Cent., or 410 degs. Fahr.), in which are found phenol, naphthalene, and a little benzene and toluene.

(c) Carbolic oils (240 degs. Cent., or 464 degs. Fahr.), containing carbolic acid and naphthalene.

(d) Creosote oils (270 degs. Cent., or 518 degs. Fahr.), which are composed chiefly of different phenols and certain quantities of anthracene and naphthalene.

(e) Anthracene oils (above 270 degs. Cent., or 518 degs. Fahr.), in which the bulk of the anthracene is found.

(f) Pitch, which remains as a residue in the retort.

A comparison of the tars from the Otto and Simon-Carvès ovens with gas tar is shown in the following table:—

* *Journal of the Society of Chemical Industry*, 1883, vol. ii., page 495.

TABLE IV.—COMPOSITION OF TARS.

		Gas Tar.		Otto Coke-ovens.		Simon-Carvès Coke-ovens.
Water	...	2·90	...	2·20	...	2·35
Light oil	...	4·00	...	3·40	...	4·24
Benzol	...	0·92	...	1·10	...	1·22
Naphtha	...	0·20	...	0·32	...	0·25
Creosote oil	...	8·60	...	14·50	...	12·10
Naphthalene...	...	7·40	...	6·70	...	9·34
Anthracene oil	...	17·40	...	27·30	...	25·50
Pure anthracene	...	0·60	...	0·70	...	0·75
Pitch...	...	58·30	...	44·30	...	44·25
Coke	...	15·25	...	5·80	...	14·46

Benzene and anthracene are the products which are chiefly recovered by the coal-distiller, the other products being sold, as a rule, in the crude state. Benzene and naphthalene are largely used in the manufacture of Sprengel explosives, such as roburite, bellite, ammonite, etc. Anthracene, the most valuable of the bye-products, is used for the manufacture of alizarin, the dye-stuff of turkey red, and from benzene, naphthalene, and carbolic acid, a host of other colours are prepared for dyeing fabrics.

(3) *Ammonia*.—This gas is derived from the nitrogen in the coal. The ammonia is evolved partly as the free gas and partly in the form of ammonium sulphide, ammonium sulphocyanide, and ammonium cyanide.

The nitrogen in coal varies between 1 and 2 per cent., of which, at the most, one-fifth, but sometimes as little as one-tenth, is actually obtained as ammonia. The following results were obtained by Dr. E. Schilling* by distilling coal in a gas-retort at 1,160 degs. to 1,220 degs. Cent. :—

TABLE V.—PRODUCTS OF DISTILLATION OF COAL.

Description of Coal.	West-phalian.	English. Baldon Gas.	Silesian.	Bo- hemian.	Saxon.	Saar.	Bo- hemian Cannel.	Brown Coal.
Total nitrogen, per cent.	1·5	1·45	1·37	1·36	1·20	1·06	1·49	0·52
Of 100 parts of nitrogen, left in coke ...	80	72	70	69	64	57	44	38
Of 100 parts of nitrogen, volatilized ...	20	28	30	31	36	43	56	63
Percentage yield of am- monia on coal carbonised	0·248	0·189	0·284	0·237	0·094	0·188	0·22	0·12
Nitrogen as ammonia on the total nitrogen, per cent. ...	13·6	10·8	17·4	14·2	6·4	14·8	12·4	20·7
Ammonium sulphate (lbs. per ton of coal) ...	22·3	17·0	25·6	21·4	8·5	16·9	19·9	11·0

In coke-ovens, it would appear that larger quantities of nitrogen are expelled than in the gas retort, Dr. Watson Smith having shown that

* *Journal für Gasbeleuchtung*, 1887.

whereas gas coke contains 1·375 per cent. of nitrogen, beehive coke contained 0·511 per cent., and Simon-Carvès coke only 0·384 per cent.

The ammonia and some of its compounds are partly absorbed by the water which is produced by the distillation, and a light brown liquid is obtained, called ammonia-liquor, but a considerable portion is carried away by the uncondensable gases, from which it is recovered by a process of washing with water. This solution of ammonia and its salts is mixed with lime, and, on heating, the gas is expelled and passed into strong sulphuric acid, when ammonium sulphate is formed, and separates out as a white crystalline body, which can be fished out from time to time. Every unit of ammonia yields 3·9 parts of ammonium sulphate, and for every unit of nitrogen evolved as ammonia 4·7 units of ammonium sulphate result. In the Otto-Hoffmann ovens, so much used in Westphalia, 1 per cent. of ammonium sulphate, equivalent to 22 to 25 lbs. per ton of coal, is obtained.

Ammonium sulphate is a valuable manure for which there is practically an unlimited demand.

The permanent gases are used, without further purification, as fuel for heating the coke-ovens and boilers.

The gases passing from the washers (specific gravity 0·399) have roughly the following composition :—

Hydrogen (H)	...	...	...	49·60
Nitrogen (N)	}	...	...	35·03
Marsh gas (CH_4)				
Olefiant gas (C_2H_4)	...	...	...	0·90
Other hydrocarbon gases	...	...	...	3·98
Sulphuretted hydrogen (H_2S)	...	...	...	0·50
Carbonic acid gas (CO_2)	...	...	...	1·78
Carbon monoxide (CO)	...	...	...	8·21
Total	...	..	...	100·00

Part of the nitrogen in coal is evolved as cyanogen, which is very valuable, as it can be converted into potassium cyanide, for which there is a large demand for use in gold recovery processes. According to Mr. Foster* 1·56 per cent. of the nitrogen in coal is evolved as cyanogen. Part of the cyanogen evolved is retained in the ammonia liquor as ammonium sulpho-cyanide and ammonium-cyanide, but the rest escapes with the gas. According to Dr. W. Leybold† about 9 to 15 per cent. of the cyanogen passes away with the gas as purified in gas-works, but as in

* *Journal of the Chemical Society*, 1883, vol. xliii., page 110.

† *Journal für Gasbeleuchtung*.

coke manufacture iron oxide purifiers are not used, it is probable that much larger quantities will pass away with the gases, as these purifiers, according to the same authority, retain 56 to 71 per cent. of the cyanogen. At present but little attention has been paid to the recovery of cyanogen from coke-oven gases, and the exact conditions of its production are not fully understood, but in gas-works a considerable amount of attention is now being paid to the subject. Various processes have been devised for the recovery of this gas, but the one which seems to be attended with the best results consists in passing the gas through a solution of caustic soda containing oxide of iron and sulphide of iron in suspension, with the object of converting it into sodium ferro-cyanide, from which the cyanide is recovered as Prussian blue. The writers understand that experiments are now being made with the object of determining the best means of recovering this gas from coke-oven gases.

From statistics, it appears that the newer types of retort-ovens yield, in addition to an increase in the weight of coke of from 12 to 15 per cent., 10 gallons of tar per ton, and 22 to 25 lbs. of ammonium sulphate. The values may be taken at 1·6d. per gallon for tar, and about £7 per ton for ammonium sulphate.* These amounts are equal to 1s. 4d. per ton for the tar and 1s. 7d. for the ammonium sulphate, subject to the cost of manufacture. If the anthracene be recovered, a better result is realized. A process for the recovery of benzene is in operation at some of the works in Germany, but it is at present a secret process.

II.—EVOLUTION OF THE BYE-PRODUCT OVEN.

Although coke-ovens from which a certain amount of bye-products were obtained had been devised even as early as the beginning of the present century, it was not till about 1878 or 1880 that ovens which really gave satisfactory results were devised. The first successful oven for the recovery of bye-products appears to have been invented by Mr. Knab, of Paris. This oven was of the Coppée or retort type, with a flue

* The prices for bye-products from 1885 to 1895 have ranged as follows :—

TABLE VI.—VALUES OF BYE-PRODUCTS.

	Kilo-grammes.	Standard Prices in Shillings at Beginning of Year.										
		1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.
Tar	1,000	45	25	15	21	35	36	39	39	29	27	27
Sulphate of ammonia	1,000	240	230	232	240	240	240	230	220	200	270	200
Benzol	100	75	40	65	65	70	63	63	45	39	31	25

under the floor, by means of which external heat was communicated to the charge, and the coking conducted in a closed chamber, the gases being taken off, and the bye-products partially recovered.

(1) *Carvès Ovens*.—Mr. Carvès improved upon the Knab oven by introducing horizontal flues, and in 1866 he built at Bessèges and Terrenoire a block of ovens with distillation-plant, which attracted the attention of specialists, and revived an interest in the study of the question. In Germany, a plant on the Carvès system was erected at Gelsenkirchen, but several important modifications in detail were introduced by Mr. Hüssener, the engineer in charge of the work. Fifty ovens were erected, having the following dimensions:—Length, 29·53 feet (9 metres); breadth, 22·64 inches (0·575 metre); and height, 5·91 feet (1·8 metres). The charge was 5·5 tons of fine riddled coal, which was equal to about 88 per cent. of the capacity of the oven, and the period of burning averaged sixty hours. The results obtained were as follows :—

						Per Cent.
Large coke ...	...	...	...	...	...	75·00
Small coke ...	...	...	...	...	...	0·80
Ash ...	...	...	...	...	...	1·20
Tar ...	...	...	...	...	...	2·77
Ammonium sulphate	...	...	...	...	...	1·10

The tar was very thin, and yielded on distillation 58·83 per cent. of distillate and 39·51 of residue (pitch), the loss being 3·65 per cent. In the tar there was 1·08 per cent. of benzol (boiling-point 88 degs. to 140 degs. Cent.), 0·39 per cent. of naphthalene, 1·37 per cent. of phenol (well purified), and 0·95 per cent. of pure anthracene.

The arrangements for taking off the gases were as follows :—A cast-iron pipe, furnished with a valve, opened into the middle of each oven, and a system of condensation-pipes was arranged on the top. The gas was then drawn through a special exhaustor to the condensation-house, and after the whole of the condensable matters had been taken out, the mixture of permanent gases was drawn through a fan and pressed back to the battery of ovens, where it was utilized for heating the side-walls and bottoms of the ovens.

This arrangement is somewhat different from that of the original Carvès oven. In the latter the gases were burned over an auxiliary fire under the floor of the oven and then passed on to the passages in the walls, through which they streamed successively, commencing at the top, and passed at last into the flue leading to the chimney. The heating

thus obtained was irregular, the walls being comparatively cool and the floor too hot, which induced Mr. Pernolet in 1870 to confine the heating by gases to the side-walls, and to heat the floor with hand-firing only.

Mr. Hüssener endeavoured to do away with the auxiliary fire, and by a better division of the gases and a supply of heated air, to obtain greater uniformity in the heating of the sides and bottoms of the ovens. The gases were conducted into a flue by means of pipes with ring-burners at their terminations, so that a fresh supply of heat was obtained at several different points. The combustion appears to be very complete, for the resulting gases were found to contain :—

					Per Cent.
Carbon dioxide	...	...	...	...	8·1
Carbon monoxide	...	...	...	...	0·4
Oxygen	...	...	...	...	0·3

(2) *Simon-Carvès Oven*.—In papers read before the Iron and Steel Institute by Mr. Henry Simon in 1880* and by Mr. R. Dixon in 1883,† an account is given of the results obtained from Carvès ovens as modified by Mr. Henry Simon, of Manchester, which are known as the Simon-Carvès ovens. These ovens do not materially differ from the original Carvès design. The side-flues are always horizontal, and are constructed in the partition-walls between the ovens. The ignited gases are drawn under the floor of each oven and then into the horizontal flues in the walls, rising first vertically to the top, and then descending through the lower flues (Figs. 2 and 3, Plate XVI.). The temperature is maintained by the introduction of jets of gas into the side flues, and a steady temperature of upwards of 2,000 degs. Fahr. is maintained during the burning of the charges of coal. In front of the ovens is a recuperator of five flues, in the second and fourth of which the heated gases circulate on their way to the chimney, and in the other three the air used for combustion in the flues is heated to a high temperature. The gases are taken off and condensed in a manner similar to that already described.

(3) *Semet-Solvay Ovens*.—Messrs. Semet and Solvay patented in 1881 a variation of this construction by building the arch of the oven upon solid partition-walls, and placing, on the inside of these partition-walls, flues constructed of thin fire-brick, which served merely as passages for the heat, and had no weight to carry. They could, therefore, be renewed without interfering with the structure of the ovens. They had the

* *Journal*, vol. i., page 137. † *Ibid.*, vol. ii., page 494.

advantage also of transmitting the heat more effectually to the charge in the oven, not only because the walls were thinner, but because there were sets of independent flues on each side of every oven. These ovens have given most satisfactory results, especially at the works of the Phoenix Iron Company, Osnabrück, and in Belgium.*

(4) *Early Otto Ovens*.—About the same time, namely, in 1881, Dr. Otto adapted the Coppée oven for recovery of bye-products, and although the Otto-Hoffmann oven has now completely superseded its forerunner, it is interesting to give a short account of it. In Dr. Otto's first arrangement, there were two gas outlets in the roof of the oven, one of which led to the exhausters and drew off the gases and steam, while the other joined the purified gases returned from the condensing-plant, and in combination with the latter, passed through, first, the side heating-flues, and afterwards the floor-flues on its way to the chimney. Horizontal passages were provided over two partition-walls for heating the air necessary to secure combustion.

The next improvement was to provide two tiers of flues beneath the ovens, in addition to the smaller cool air-flues, which were again below these. The burning gases were then so conducted that they entered first into the lower of these two flues, from which vertical passages through the walls of the ovens conducted them to the roof, where they passed over a mid-rib, and descended the adjoining vertical flue till they reached the upper flue immediately under the floor of the oven. At the end of this flue, they were conducted by a coupling pipe, which passed to the outside and into the adjoining oven. By this means, the heat which the gases retained on leaving the first oven were utilized in the next oven in the following manner :—In the first twenty-four hours after the filling of the ovens, the gases were simply drawn off, purified, and returned to the second oven, and there mixed with the waste gases coming from the upper bottom-flue of the first oven. The object of this arrangement was to provide the necessary heat when the charge was partly burnt off, and when the heat arising from the oven would therefore be partly spent, and in the result an equable heat was maintained throughout the whole of the burning time. After twenty-four hours, the second of the ovens was drawn and filled, and the dampers were reversed. Half the ovens were drawn every twenty-four hours, and each oven burnt for forty-eight hours. Each oven gave off a supply of crude gases and steam, which passed through the roof to the condensation-plant.

* *Trans. Fed. Inst.*, vol. ix., page 54.

The working thus alternated from one to the other of the pair of ovens, and the ovens never having cooled, the effect upon the charge of freshly-filled coal was exceedingly rapid, which was the main object to be attained, as it not only produced denser coke, but a better quality of bye-products. If it was desired not to take the whole of the gases to the condensation-plant, the burnt gases could be intermixed with the purified permanent gases and burnt with them in the hot flues. If, however, it was desired to work the flues separately, all that was required was to connect the top flue with that which led to the chimney, instead of with the adjoining ovens.

(5) *Introduction of the Regenerator Principle in Coking Apparatus.*—

The improvements in the last-mentioned coke-ovens, tended to a better utilization of the hot gases, and strenuous efforts were made to improve the heating of the air for assisting the burning of the gases and to increase the temperature of the latter as far as possible in order that the thermal effect of the burning of the mixture might attain the desired maximum, but it was only when the addition of the heating arrangements on the principle of the Siemens regenerator was introduced that a sufficient increase in the heating-temperature was obtained.

The first embodiment of the regenerator principle was due to Mr. Gustav Hoffmann, who patented it in May, 1881; and the original idea has been developed in his subsequent patents, extending up to 1889. A complete coke-oven plant, with bye-product recovery on the Hoffmann principle, was erected at the Pluto mine, in Westphalia, in 1884.

The co-operation of Dr. Otto with Mr. Hoffmann has gradually brought this type of oven into the foremost place, and the large majority of the coke-ovens now working in Westphalia are on this principle.

The basis of the design is that on each side of the row of coke-ovens there extends a pair of regenerators (or large arched flues) filled with firebricks, arranged in chequer-form, which, by means of the well-known Siemens reversing-valve, is alternately placed in connexion with the supply of burning gases and air and the oven-flues, or with the oven-flues and the chimney.

The ovens are constructed with a flue of considerable area running beneath the floor of the ovens from side to side, but separated in the centre by a partition. These floor-flues are in connexion with a number of vertical passages, about 32 in number, which pass up the centre of the division-walls between the ovens, and enter at the top into another horizontal flue.

The heated air and gases from one of the regenerators enters the flue below the floor of the ovens and passes up the first vertical passages in the oven-walls into the upper horizontal flue until it reaches the middle of the oven, when it descends by the vertical passages in the other half of the oven into a flue beneath the oven-floor, and thence into the second regenerator, and so on to the chimney (Figs. 4, 5, and 6, Plate XVI).

For various reasons, the previous heating of the gases has been abandoned, and they are now allowed to enter the floor-flues direct from the condensation-plant by means of pipes, as described in connexion with the Simon-Carvès oven. By this means, it is believed that the liability to explosions which might damage the ovens is to a great extent avoided, and the amount of gases admitted can be regulated so as to obtain the best possible results from its combustion.

(6) *Latest Type*.—The latest form of Otto coke-oven departs somewhat widely from the type just described. The regenerator flues are abandoned, and instead a system of burners on the Bunsen principle, in rows of eight, are placed in an arch under the side-flues of each oven. A supply of gas is conveyed to these burners by a cross pipe connected with a gas-main running longitudinally under the fronts of the coke-ovens. The amount of gas for each group of burners can be exactly regulated, and the temperature can be raised to any desired degree and maintained constant throughout the burning of the charge. The floors of the ovens are not directly heated (Fig. 7, Plate XVI).

The normal type of Otto oven has the following dimensions:—Length, 32·81 feet (10 metres); height, 5·58 feet (1·70 metres); and width, 23·62 inches (0·60 metres), slightly conical. Such an oven will produce 800 tons of coke per annum.

There remains to be described two types of coke ovens which have recently been designed, namely, those of Messrs. Collin and Brunck.

(7) *Collin Oven*.—There are two types of Collin ovens, the vertical and the horizontal. The horizontal oven is somewhat similar to the Coppée oven in general design, with certain important modifications. It is usually about 30 feet long, and varies in width from 1 foot 8 inches on the side next the ram to 2 feet at the outlet side. The floors are paved with large firebrick blocks, which it is believed will require less repair than the usual brick floor. The introduction of the air is so arranged that the air from each side is conducted almost to the middle, and also

to one-fourth of the length of the oven, in divided passages. Thus a very equal burning of the gases throughout the whole length of the oven results, and no part of the charge requires longer firing than the rest. A considerable number of these ovens have already been built, including some at Ackton Hall colliery, Pontefract, and others are in course of erection.

Quite recently, Mr. Collin had considerably modified the arrangement of side-flues, and adopted the horizontal instead of the vertical type. The arrangement (which is shown in Figs. 8, 9, 10, 11, and 12, Plate XVII.) at first sight appears to have a close resemblance to the Semet-Solvay, but unlike the latter, the flues are constructed in the division-walls of the oven, and extend only half-way across, the hot gases passing forwards and backwards twice before going into the waste-flue. The temperature of the gases is renewed by the admission of unburnt gas which is introduced into the flues by means of metal-pipes, both at their outer ends and at their inner ends in the centre of the oven. It is claimed for these ovens that the temperature obtained is very high and uniform, and that by the arrangement of double horizontal flues the cooling of the walls of the ovens which are being drawn is to a great extent prevented by the heat given off from their neighbours which are burning.

The upright Collin coke-oven has not yet been largely adopted. As in the case of the Appolt oven, it is emptied by opening the bottom of the oven and allowing the coke to drop out.

(8) *Brunck Oven*.—The Brunck oven, which claims to combine the advantages derived from the separate flues of the Semet-Solvay oven with the vertical arrangement of the flues adopted in the Otto-Hoffmann oven, has been fully described in the *Transactions of The Federated Institution of Mining Engineers*.* It appears to be giving satisfactory results, and at the present time a considerable number are in course of erection in Germany. Practical difficulties had, however, presented themselves (chiefly due to the position and construction of the waste gas-flues), and these would have to be overcome before the Brunck oven could be considered an unqualified success.

All the coke-ovens described are usually erected in blocks of 30 or 35 ovens each. Each oven has two rising-mains 10 inches in diameter with outlet valves, which connect the ovens with the general mains.

* Vol. ix., page 47.

The latter are 26 inches in diameter, and run along the whole length of the block of ovens. They are of cast-iron, with welded flanges, and without joints or bolts, so as to render them easier to clean out. The waste gases are utilised for boiler heating.

*Condensing-Plant.**—As in ordinary gas-works, the volatile matters, which leave the ovens at a temperature of 600 degs. to 700 degs. Cent., are brought to the condensing-plant by exhausters. Before the gases enter the condensing-apparatus, they pass through three dust-separators. These are vertical cast-iron cylinders 20 feet high and 6 feet broad. The gases pass slowly through these columns and encounter a spray of weak ammonia-water, by means of which the dust is thrown down. These columns also act as coolers, and on leaving them the temperature of the gases is greatly reduced. The spray takes up ammonia, and flows with the thick tar into a ground tank, which will hold 320 tons, into which the condensed products pass and separate according to their respective specific gravities.

The gases then pass through two rows, each consisting of four vertical gas-coolers. These are 21 feet high, and contain eighty-eight cooling pipes 4 inches in diameter, so that a cooling-surface of 2,300 square feet is obtained. Cold water drips on these pipes, and the gases are efficiently cooled. The precipitated products flow into the ground tank already mentioned.

From the gas-coolers, the gas passes through three purifiers to the special washing apparatus. The purifiers are 4 feet high and 6 feet 6 inches square. The gas is again soaked in ammonia water, and gives up almost all the remaining tar-products, which, with the enriched ammonia-water, flows into the tank. After passing through these purifiers the gas passes through four exhausters, each of 80,000 cubic feet capacity at 80 revolutions per minute. Two of these exhausters are in use at one time, and the other two are held in reserve. Behind the exhausters, which now force the gases onward, stands a round cooler 5½ feet in diameter, and 25 feet high, with 91 cooling-tubes, each 3 inches in diameter. From here, the gas passes at a very moderate temperature (about 25 degs. to 30 degs. Cent.) into three scrubbers. These are 9 feet in diameter, and 9½ feet high. Each scrubber is divided into seven parts, separated by horizontal partitions. The gas on leaving the scrubbers has

* These particulars are taken from Mr. Simmerbach's paper on "Die Fortschritte der Koksfabrication in Oberbergamtsbezirk Dortmund in den letzten 10 Jahren." *Zeitschrift für das Berg-, Hütten- und Salinen-wesen im Preussischen Staate*, 1896, vol. xliv., page 402, and plates.

parted with the last traces of ammonia. It now passes into a gas-holder 27 feet in diameter, under 3 inches of water-pressure. Thence the gas is conveyed by a cast-iron main (12 inches in diameter) to the coke-ovens. By means of a valve the gas can be turned on to either of the two blocks of ovens, to which it is led by two ranges of pipes 10 inches in diameter. Branch-pipes take off a supply for each separate oven as required, each of which is fitted with a nozzle-cock.

In the further treatment of the ammonia-liquor, it is pumped into a tank 20 feet long, divided into two compartments. One of these is for the strong liquor, which goes direct to the ammonia-factory, and the other compartment is used for the weaker liquor from the scrubbers.

In the ammonia-factory there are three distilling-apparatuses, each yielding about 6,600 gallons per twenty-four hours, in which the ammonia-liquor is boiled by steam. The steamed ammonia flows into leaden boxes under leaden bells, and is mixed with sulphuric acid of 41 degs. Baumé strength. In these tanks the ammonia is absorbed by sulphuric acid, and becomes ammonium sulphate. The steaming and manufacture of ammonium sulphate requires from 12 to 19 hours for fat coals, and 20 to 40 hours for lean coals.

Near the ammonia-tank is a large tar-tank, into which all the tar from the low-level tanks is pumped. There is also a tank of clear water for the coolers, etc.

The engines for driving the condensation-plant, pumping the water, and driving a fan to force the air through the regenerator-flues of the coke-ovens are in duplicate—one used during the daytime, and the other at night. They each have cylinders 16 inches in diameter by 26 inches stroke, a fly-wheel 9 feet in diameter, and a driving-pulley 6 feet in diameter and 2 feet wide.

Fig. 13 (Plate XVII.) represents a Collin condensation-plant, and two batteries of coke-ovens.

CONCLUSIONS.

Coke.—There can be no doubt that the flame and smoke which issue from open coke-ovens in Britain represent a large amount of money lost, not only in bye-products but in coke. In retort-ovens 15 to 20 per cent. more coke is usually obtained of a harder and denser nature than in bee-hive ovens. For a time, the coke produced in retort-ovens may suffer in price on account of its duller appearance, but the coke now made in the best ovens is really so good that it can not be long before this prejudice is overcome, and its fair market value

obtained. When the ovens are in good order, there appears to be very little spongy coke made, but this result can only be obtained by making the ovens of the correct width to suit the nature of the coal to be coked. In the case of a rich coal, the oven should be made wider than in the case of a poor coal. The temperature yielding the best results will also differ with different classes of coal, but, generally speaking, higher temperatures produce the best results.

With retort-ovens the labour is less costly than with bee-hive ovens. The pushing out of the whole charge by means of a ram in about two minutes is obviously a simple and economical way of effecting the discharge, and what is still more important, the temperature of the oven walls is lowered comparatively little, and the fresh charge when put in is instantaneously ignited. The number of men required for a block of ovens is as follows:—One man at the ram-engine, one man at the windlasses to raise the oven-doors, and two men to water the coke. The filling of the ovens, and the loading of the coke into waggons is performed by other men.

Bye-products.—The quantity of bye-products to be obtained from any description of coal depends entirely on its composition, but while it may be said that almost any kind of coking coal can be coked in retort-ovens (which is not the case with bee-hive ovens) it is the richer bituminous coals from which satisfactory results in the matter of bye-products can alone be anticipated. The cost of the provision of the necessary plant may be taken roughly at about 10s. per ton of fuel coked per annum, or £25,000 for 50,000 tons of coal. The results obtained may reach in favourable cases at the present prices of tar, sulphate of ammonium, and benzol as much as 4s. 6d. per ton of coal coked, or £11,250 per annum; a sum which, after allowing a liberal sum for the redemption of capital, leaves a margin of profit not to be obtained in other branches of the coal trade. If to this profit on bye-products be added the value of the extra 15 per cent. of coke obtained from retort-ovens, and the economy in labour, it will be seen that the policy of adopting this method of coking offers very great inducements to the expenditure of the necessary capital where the coals to be treated possess the necessary qualities.

On the other hand, there are considerations which require very careful consideration, and especially in this country.

Working.—The working of the ovens is perhaps a more important question than appears at first sight. Bye-product retort-ovens must

be worked without intermission night and day, Sundays included, and nothing must allow this working to be intermitted. If the ovens are not drawn and re-charged, the moment the coking process is completed the temperature falls, and the next charge is not properly burnt. Provision must be made for a supply of slack coal for holidays or stoppages of the mines, due to accidents. In this country, owing to the frequency of labour disputes, this is a more serious contingency than it is in Germany, where these unfortunate occurrences are less frequent. In case of an extended strike in a district, slack coal will not be procurable, and the ovens will of necessity have to be extinguished, and such a stoppage will do the ovens more harm than months of regular working. The pipes conveying the bye-products require constant care, or they will soon become closed and so cause a stoppage. In the case of an over-production of coke, the coke will either have to be stocked or forced upon the market at very low prices. With a view to minimize the chances of breakdown of any part of the plant, involving interruption of working, all German plants are erected in duplicate and worked alternately, so that one plant can be repaired or cleaned while the other continues at work.

Results.—The actual amount of bye-products obtained from 60 Otto coke-ovens at the Constantine the Great colliery, Bochum, is stated to be as follows :—Ammonium sulphate, about 1·37 per cent., or 80 to 90 tons per month ; tar, about 2·1 per cent., or 200 tons per month ; the coal coked being about 7,000 tons per month.

We have seen other results equal to and even better than this, but as the amount of bye-products depends on the composition of the coal in each case, no figures can be taken as a guide to the yield which some other coal will give. This variation in the produce from different coals should be borne in mind when comparing the results obtained from different types of ovens. Thus with Durham (busty-bank seam) coal, the average result of twelve months' working of 70 Simon-Carvès ovens at Malton colliery gave 62 tons of coke per oven per month ; the amount of tar obtained was 4·18 per cent. ; of sulphate of ammonium, 1·5 per cent. ; and 150 gallons of 80 per cent. crude naphtha per month. The yield of coke from these ovens has, however, been lately considerably increased. Equally satisfactory results have been obtained from Semet-Solvay coke-ovens.

Waste Heat.—The patentees of various retort-ovens are inclined to overstate the amount of heat available for boiler-heating. It may be

said, however, that 60 ovens are usually supposed to be capable of heating about five Lancashire boilers (8 feet in diameter), the steam pressure being about 120 lbs. per square inch. Water-tube boilers also are in use with gas-firing, which are stated to yield very good results.

Benzol and Cyanogen.—The last development is the erection of plants for the recovery of benzol. These plants are stated to be quite successful, but the process is carefully kept secret. The cost of a benzol plant is said to be about £10,000. Although cyanogen is not yet recovered on a working scale there is little doubt that this important development is on the eve of accomplishment.

When the vast number of valuable substances to be obtained from the distillation of coal are considered, one cannot doubt that the German chemist will continue to add to the number of valuable products now wasted wholesale in the production of coke through the ignorance of manufacturers. What has already been accomplished is a remarkable testimony to the value of pure science to practice, and it should be remembered that not only does the recovery of waste products enrich German collieries, but it constitutes a weapon in their hands enabling them to compete with us in the production of cheap coke, and the coke trade of our country, if unprovided with similar means of revenue, must inevitably suffer.

The CHAIRMAN said that one of the most absorbing questions of interest at the present time amongst soft coal collieries was the production of coke and the description of coke-ovens to be erected. Durham coking collieries would not last many years longer, and he was assured that in a few years it would be necessary for more coke-ovens to be erected in the Yorkshire district. Those members who knew something of coking in the county of Durham—he had had the management of a coking colliery in that county—would find that coke from the open-topped bee-hive coke-ovens was hardest, and contained less sulphur than coke from any other form of oven.

The Germans did not appear to use coke for the same purposes as they did in this country. What suited the German furnaces might not suit British blast-furnaces. Care would be necessary in the introduction of retort coke-ovens into the Yorkshire district, otherwise a coke might be produced which was not required.

Mr. DURNFORD (Acton Hall colliery) stated that 50 coke-ovens of the Collin type had been erected at Acton Hall collieries. They were started last year, and up to the present time, they had given satisfactory results. He could state, without the possibility of contradiction, that the coke produced, when once they had overcome the objections to its appearance, was equal to the best South Yorkshire coke. The average output was 500 tons per week, the time of burning the coal in the ovens was 44 to 48 hours, and the average amount of sulphur was only 1·06 per cent. The Barnsley bed in that part of the country was not equal to the seam as worked in South Yorkshire, as it contained more dirt and pyrites, which had to be removed by washing. The coke was harder than any coke which went from their county, and most of it was used at blast-furnaces. He had an opportunity a short time ago of seeing the bye-product arrangements at Messrs. Peases' Roddymoor colliery, Durham, and he believed that a bye-product plant would yield satisfactory pecuniary results. The coke was as good as when made in bee-hive coke-ovens.

Mr. C. E. RHODES (Aldwarke Main colliery) moved a vote of thanks to the writers for their interesting paper on a very important subject. The results of many experiments with plants for the recovery of the bye-products of coke-making, which had been made in the last 20 years, would not induce people to adopt that branch of coke-making with any amount of enthusiasm. There was in this country a great prejudice as to the character and appearance of coke, and there was a difficulty in selling it. The experience of those using it was that for all practical purposes it was equally as good, and gave as good a result for blast-furnace purposes as bee-hive coke. Whether it could be made as useful for steel-melting and other processes had yet to be proved. Such a plant as that described by Mr. Walker to obtain the bye-products involved a heavy outlay, and before committing themselves to undertake such an outlay they should proceed with considerable caution, and gather all possible information.

Mr. SCHROLLER (Durham) wrote that a great deal of the divergence of opinion of engineers on the merits or demerits of the different coke-oven constructions now attracting the attention of owners of collieries, blast-furnaces, and foundries rested upon the outward appearance of the coke. From the facts deduced so far, it was extremely doubtful whether, for instance, vertical side-flues had any effect upon the apparent better quality of Westphalian coke, and in support of this he might mention as

a fact that at Bilbao, Spain, where there were 140 Simon-Carvès coke-ovens working with horizontal flues, the coke produced when using Westphalian coal, which frequently had to be done, was of as good an appearance as any of the best coke produced in Westphalia itself in vertical flued-ovens. In engineering, like any other science, every operation necessitated time, if it was required to be done with the utmost efficiency. For this reason, he called vertical-flued coke-ovens, scientifically speaking, a barbarism, because their length of 5 or 6 feet was not sufficient to give the gases the necessary time to part with the requisite percentage of heat units when in contact with the side-walls of the ovens. In the case of Otto coke-ovens, this was demonstrated by their constructors themselves in more than one way. They had, for instance, of late, tried the effect of changing at quicker periods the current for the production of hot air for combustion in their regenerator; and he was told that they were changing the current now every 20 minutes against every 2 hours, as formerly; and further, more recently still, the want of greater heat had driven them to the extraordinary complication of introducing many hundreds of Bunsen burners, to the extent of about 1,000 in the case of a group of 60 ovens. He did not think that British workmen would lend themselves very readily to attend efficiently to such complicated arrangements.

Even if Dr. Otto was not using this arrangement now, it was in itself the severest condemnation of his former coke-ovens, for it showed that Otto coke-ovens required more heat at the bottom than they actually attained by the present ordinary construction, and that he was trying to get it by this complicated, unreliable means, requiring untold attention.

On the other hand, the continuous horizontal side-flues of the Simon-Carvès construction of coke-ovens, together with the application of hot air from the recuperator, appeared to offer all that was necessary for the efficient utilization, in every part of the charge, of the heat of the gases of combustion. The following temperatures were ascertained in the different flues (by a Gilterman calorimeter) at one of the Simon-Carvès coke-oven establishments, where there was one burner to each oven, and a coal was used containing only 20 to 21 per cent. of volatile matter, viz.:—

					Deg. Cent.
Sole-flue	...	...	...	...	1,330
Recuperator	...	...	...	...	562
Top horizontal flue	...	...	...	...	1,200
Two middle horizontal flues	...	...	...	...	1,320
Two middle horizontal flues	...	...	...	...	1,130
Lower horizontal flue	...	...	...	...	1,150

The flues of the vertical type of construction cannot be properly inspected when at work as can the horizontal flues of the Simon-Carvès coke-oven; and as in the case of the Otto vertical flues the gases naturally go by the shortest way to the outlet, some parts of the oven-charge, and notably the upper part near the doors does not become coked, hence it was customary not to fill the oven quite full against the doors, but to leave a vacant triangular space at the doors. In comparing the Simon-Carvès British with the Otto Westphalian practice, as regards time required for coking, it should be borne in mind that Westphalian coal contains little tar and cokes consequently faster than, for instance, some of the highly bituminous British coals. And as regards the good appearance of the Otto Westphalian coke it had probably yet to be proved whether this good appearance was not being obtained at the expense of a diminished yield of bye-products. He would also like to mention that the greater solidity of construction of the Simon-Carvès ovens was the result of about 25 to 30 years' practical experience.

Mr. LONGDEN (Stanton) seconded the vote of thanks to the writers for their paper upon a highly interesting subject—one in which other people were interested besides colliery proprietors, as blast-furnace owners they had unfortunately to buy coke, and the question of its brightness was one which they could not afford to ignore. As far as they were concerned, they (at Stanton) preferred coke burnt in bee-hive coke-ovens, but if there was advantage to be gained by erecting plant for the recovery of the bye-products, considering the price to which sulphate of ammonia had fallen and to which it might go, they, as mining engineers, should be to the fore in the matter.

The motion was agreed to.

The meeting was then closed.

MIDLAND INSTITUTE OF MINING, CIVIL, AND
MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE QUEEN'S HOTEL, LEEDS, APRIL 24TH, 1897.

MR. GEO. BLAKE WALKER, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentleman was elected, having been previously nominated :—

ASSOCIATE MEMBER—

MR. GEORGE HENRY NUTTALL, Deputy, 67, Craven Road, Darnall, Sheffield.

BARNSELY MINING SCHOOL.

The PRESIDENT said that there were now four bodies in Barnsley receiving grants from the County Council, all carrying on their work on independent lines, and the result was a waste of money and of teaching power. His paper contained a description of the Bochum Mining School, where the students studied four hours a day after the usual day's work was over in the mine. He recognized very clearly that they could not ask their local young men to give up all their time as the German young men were willing to do, and it was part of the proposal that they should be invited to give three hours on four days of the week, that a school should be founded to be called the Barnsley Mining and Science School, where instruction would be afforded in mining engineering and textile technology, mechanical engineering, and other subjects in which the town and district of Barnsley was interested, together with instruction in the sciences which were necessary for the proper understanding of these practical subjects. There should be a resident science master with competent assistants, teachers of engineering, drawing, and, perhaps, building-construction, etc. The funds now spread over four different

bodies should be combined, and would form an adequate endowment for such a school. The County Council, School Board, and Corporation of Barnsley would have the right of granting scholarships, and outsiders could attend on payment of fees. It should be an absolute condition, that those persons who became students of this school, even if they were a small number, should give four days a week and three hours per day to their studies. It might be argued that students would not attend. He would be content if the beginning was small. He could only hope that people would become more impressed with the value of technical instruction, that they would make the sacrifice, and that they should have in the end a valuable institution.

Mr. W. E. GARFORTH (West Riding collieries), approved of the suggestion made by the President, and thought that the scheme was capable of affording the same advantages to the people of Barnsley and district as he knew from actual visits to Bochum and other towns in Westphalia that they were receiving in Germany.

Principal BODINGTON (Leeds) remarked that in any proposal to spend public money in organizing a school more or less on the model of the school at Bochum, or any other continental school, the members must not blind themselves to the very different conditions with which they had to deal from those in Germany. In the first place, it was essential that in every meeting at which a subject of this kind came up for discussion the very backward state of British elementary education should be carefully kept in view. One great difficulty in getting students at the Barnsley school in the past had been—and he believed in the immediate future would be—that the elementary education of those who might be expected to attend the classes was so defective that they could not take the advantage which they should do of technical training. In addition to the instruction given at Barnsley, there had been a good deal of peripatetic instruction in coal-mining given in the district. In some cases an average attendance of 40 or 50 had been present, in other cases an average attendance of 80 or 90, and in other cases a larger attendance still. Out of the large numbers who attended the peripatetic lectures, very few presented themselves for examination. The examinations had been conducted by Prof. Merivale, of Newcastle-upon-Tyne, who said that, with few exceptions, the elementary education of the students was so deficient that though they possessed the knowledge they could not express themselves. Neither their writing, nor spelling, nor power of expression was such as to enable them to answer a simple paper

containing the few elementary problems dealt with in the first six lectures on coal-mining. The President knew that a different state of things prevailed in Germany. All who had paid attention to German education knew that German elementary education was better, was carried further, and by means of night schools was much better retained. He did not think that, until they had removed that stumbling-block, they should at all realize the expectations formed of the centre at Barnsley of the kind spoken of or any other centre. In the second place, they must remember that the governments of France and Germany attached a value to scientific training which was not attached to it here. Looking at the extremely practical character of our people, and their great devotion to sports in the form of physical exercises, and the various distractions to anything like continuous study, he did not believe, until they got more motive power behind young men, that the abstract desire for study would fill their schools. Apart from that, he was much afraid there was little hope that they would get young men to attend twelve hours a week after the exhausting labour of the mine. In Germany, the hours of instruction were so arranged that men could attend the morning classes when on the afternoon shift, and the afternoon classes when on the morning shift. He might add that in the very admirable sketch which the President gave of the ideal education of the mining engineer, he drew out a programme which they were ready to meet at the Yorkshire College or the Firth College so soon as students would enter for it.*

DISCUSSION UPON MR. GEORGE DUNSTON'S PAPER ON
"THE EASTERN EXTENSION OF THE MIDLAND COAL-
FIELD, AND THE EXPLORATION AT SOUTHCAR. †

Mr. J. NEVIN (Mirfield) remarked that there was little dip between Cadeby colliery, 3 miles west of Doncaster, and the bore-hole at Southcar, which was 5 or 6 miles south-east of Doncaster. At Cadeby colliery, the Barnsley coal-seam was over 2,100 feet deep, and at Southcar bore-hole it was only 3,143 feet, so that in a distance of 8 miles they had only a dip of about 1,000 feet. The measures must be lying much flatter between these places than they were to the west of Cadeby, unless there were some large faults. The cores showed that the measures were almost flat. The thickness of the red measures, which were heavily watered, would make it a very difficult colliery to sink. If the water went down to a depth of

* *Trans. Fed. Inst.*, vol. xii., page 132.

† *Ibid.*, page 515.

1,000 feet, very heavy tubing would be required. The thinness of the coal-seam might be accounted for by the great weight of the rods. When the diamond drill met a coal-seam, the rods sank a few inches, the water washed out the coal, and therefore a seam which showed 10 or 11 inches might possibly be found as thick as 3 feet. The coal-seams were there and in their proper position, and were, perhaps, thinner than at the western collieries.

The PRESIDENT remarked that the collieries east of Doncaster would be sunk through a large area, drained by extensive artificial drains. The result of mining at Southcar and other places in the neighbourhood of Doncaster would be to convert the surface into lakes, unless the level of the ground was raised artificially; consequently anyone undertaking a colliery enterprise would not only have to contend with the water below ground, but also with the surface-water, for which he would have to find a way of escape. It might affect not only the lands immediately in occupation, but also neighbouring lands, as the entire drainage-system of the district might be disorganized and very heavy claims might ensue.

DISCUSSION ON MR. T. B. A. CLARKE'S PAPER ON
"ELECTRIC COAL-CUTTING IN LONGWALL-FACES."*

Mr. W. E. GARFORTH said that, up to the time when he conceived the idea and introduced the deep-cut machines about $4\frac{1}{2}$ years ago, the depth of the cut was usually from 3 feet to 3 feet 6 inches. The machine cut $5\frac{1}{2}$ feet under, and had cut as much as 102 linear feet per hour, and sometimes now only one shot was fired per 250 tons of coal got. The height of cut had been increased from $3\frac{1}{2}$ to 5 inches, really $6\frac{1}{4}$ inches, which, with the improved form of cutter, did not require additional motive power. He attributed all the advantages that they had gained and the increased wages that the men were paid to this extra depth of cut. The workman instead of taking $3\frac{1}{4}$ feet before him could now take $5\frac{1}{2}$ feet without the coal wedging itself. The output was increased from 3 tons 5 cwts. with hand labour to 6 tons 2 cwts. with machine-cutting per day. The getting prices had been reduced from 2s. $1\frac{1}{2}$ d. per ton to 1s. $4\frac{1}{2}$ d. in the Silkstone coal-seam, and from 2s. $4\frac{3}{4}$ d. to 1s. $4\frac{1}{2}$ d. in the Haigh Moor coal-seam. By means of improved tool-holders, the cutters are set out the exact distances from the centre of the wheel so that 13 or 14 cutters are at work instead of 7 or 8 cutters by the old system.

* *Trans. Fed. Inst.*, vol. xi., page 492; and vol. xii., page 458.

Mr. R. ROUTLEDGE (Garforth colliery) asked, as there would be a space of 7 feet, without timber, when the coal was dropped, whether any difficulty had occurred from the roof?

Mr. GARFORTH said that so far they had had no difficulty, although the distance was about $8\frac{1}{2}$ feet. Getting-out the coal and timbering was practically the same with machine as by hand labour. The line of fracture after the coal-cutting machine was straight, whereas when working by hand there was a crooked irregular line of fracture, which prevented the coal from breaking so freely as on the machine-cut face. In the Haigh Moor seam, with $3\frac{1}{2}$ to 5 feet of clod, immediately above the coal and very liable to break down, they used less timber because the face went forward faster, and they sooner got under a "green" roof. In the Silkstone seam, they used the same value of timber, but they had had fewer accidents than when holing by hand. The machine had cut 828 linear feet in two consecutive periods of 8 hours, by $5\frac{1}{2}$ feet in depth, or about 2,200 square feet per shift of 8 hours.

Mr. T. B. A. CLARKE (Lidgett colliery) remarked that the results quoted by Mr. Garforth were very good. Much depended on the material in which the cut was made as to the time that the cutters lasted before they were changed. He thoroughly endorsed the statement that increasing the depth, or rather the width of the cut from $3\frac{1}{2}$ to 5 inches did not necessarily mean absorbing power, as it liberated the wheel, reduced the friction, and enabled the workmen to get down the coal with greater facility. At Lidgett colliery, the cut was only 4 feet 6 inches, but machines were being introduced to cut to a depth of 5 feet 6 inches. It was obviously a most important thing that the work should be thrown equally on all the cutters of the wheel rather than on a few, and such an arrangement should prove very valuable, because a great deal of the trouble met with in coal-cutting machines was occasioned by the difficulty of getting the cutters into proper position, keeping them tight to their work, and keeping them sharp and in good working order.

The PRESIDENT said that there was no doubt they were on the eve of a very great change in a great many directions in coal-mining. For the last twenty years, the mining engineer had been gradually awakening on the subject of coal-cutting. He was only beginning to realize that there were practical machines, and within the next ten years the members would see an enormous development of mechanical work in mines.

DISCUSSION UPON MR. HY. E. MALTBY'S PAPER ON "THE ENLARGEMENT OF A SHAFT AT LIDGETT COLLIERY, WITHOUT INTERRUPTION OF COAL-WINDING." *

Mr. T. W. H. MITCHELL said that Mr. Washington had had the widening out of a staple pit from 6 feet to 9 feet at Mitchell Main colliery, and he had carried out the work successfully, without interrupting the ventilation, by using a grid upon which the man worked. He used the winding-rope as a centre-line; removed 18 inches all round the pit; and bricked on from each crib as he came to it. The *débris* was thrown below the grid, and was filled into tubs at the bottom of the staple.

DISCUSSION ON DR. JOHN HALDANE'S PAPER ON "THE CAUSES OF DEATH IN COLLIERY EXPLOSIONS."†

Mr. E. W. THIRKELL remarked that Dr. Haldane pointed out that invariably workmen ran, after an explosion, by way of the main haulage-road to the downcast shaft—and to that he attributed by far the greater proportion of deaths—instead of not doing anything but lying down and keeping still. Dr. Haldane also pointed out that after an explosion there was in many instances sufficient fresh air to support human life, and cited an instance where in one case 36 hours had elapsed, and owing to the discretion of some officials a large number of men escaped. Men escaped after 30 hours at Parkslip colliery because they had erected a thick stopping to keep back the after-damp. He pointed out the necessity of proper arrangements being made at every colliery between the manager and deputies to provide for anything which might occur. Nobody would admit that his colliery was liable to explosion in the ordinary sense of the word; but explosions did occur, and when a member read a paper with practical ideas it was their duty to put those ideas into practice. It was most important that every deputy in a pit who had charge of a district should know precisely what to do in case an explosion happened—in order to save as many of his workmen as possible by withdrawing them from the point of danger.

Mr. R. ROUTLEDGE (Garforth colliery) remarked that, at Micklefield colliery, some of the men had erected brattice-cloth on each side of them. The explorers reached them in 26 hours, but they were all dead. It was very desirable to suggest what workmen should do after an explosion, but they often had not time to do it.

* *Trans. Fed. Inst.*, vol. xii., page 642. † *Ibid.* vol. xi., pages 502, 519, and 559; and vol. xii., pages 60, 102, 432, 453, and 533.

MIDLAND INSTITUTE OF MINING, CIVIL, AND
MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE BULL HOTEL, WAKEFIELD, MAY 29TH, 1897.

MR. G. B. WALKER, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

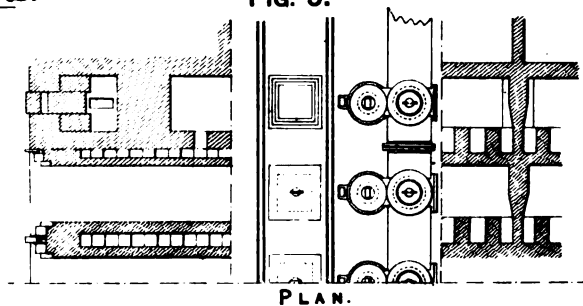
The following gentleman was elected, having been previously nominated :—

MEMBER—

Mr. JAMES LINDAY, Colliery Manager, Nostell Colliery, Wakefield.

Mr. HAROLD BONSER read the following paper on the “Recovery of Cyanogen and other Residual Products from the Waste Gases of Coke-ovens” :—

Fig. 5.



OTTO-HOFFMANN COKE OVEN.

Fig. 4.

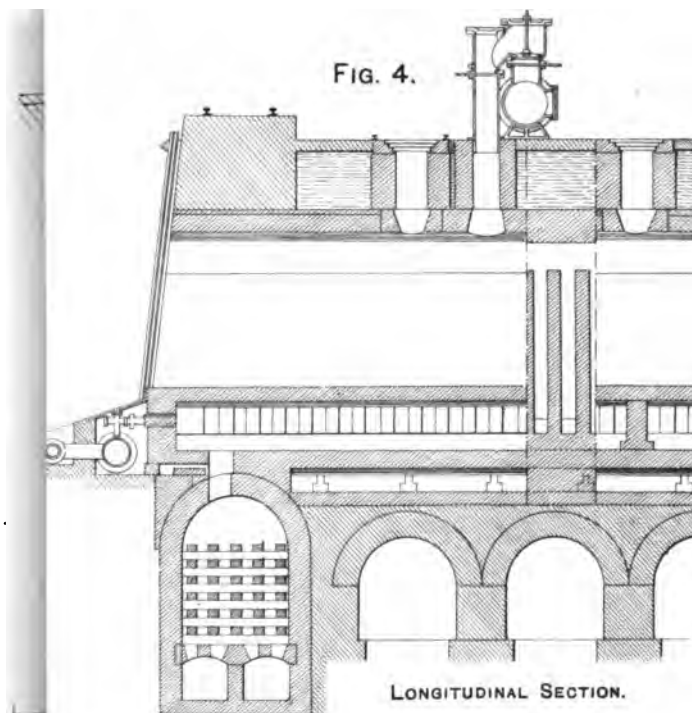
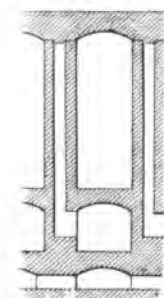


FIG. 6



CROSS SECTION.

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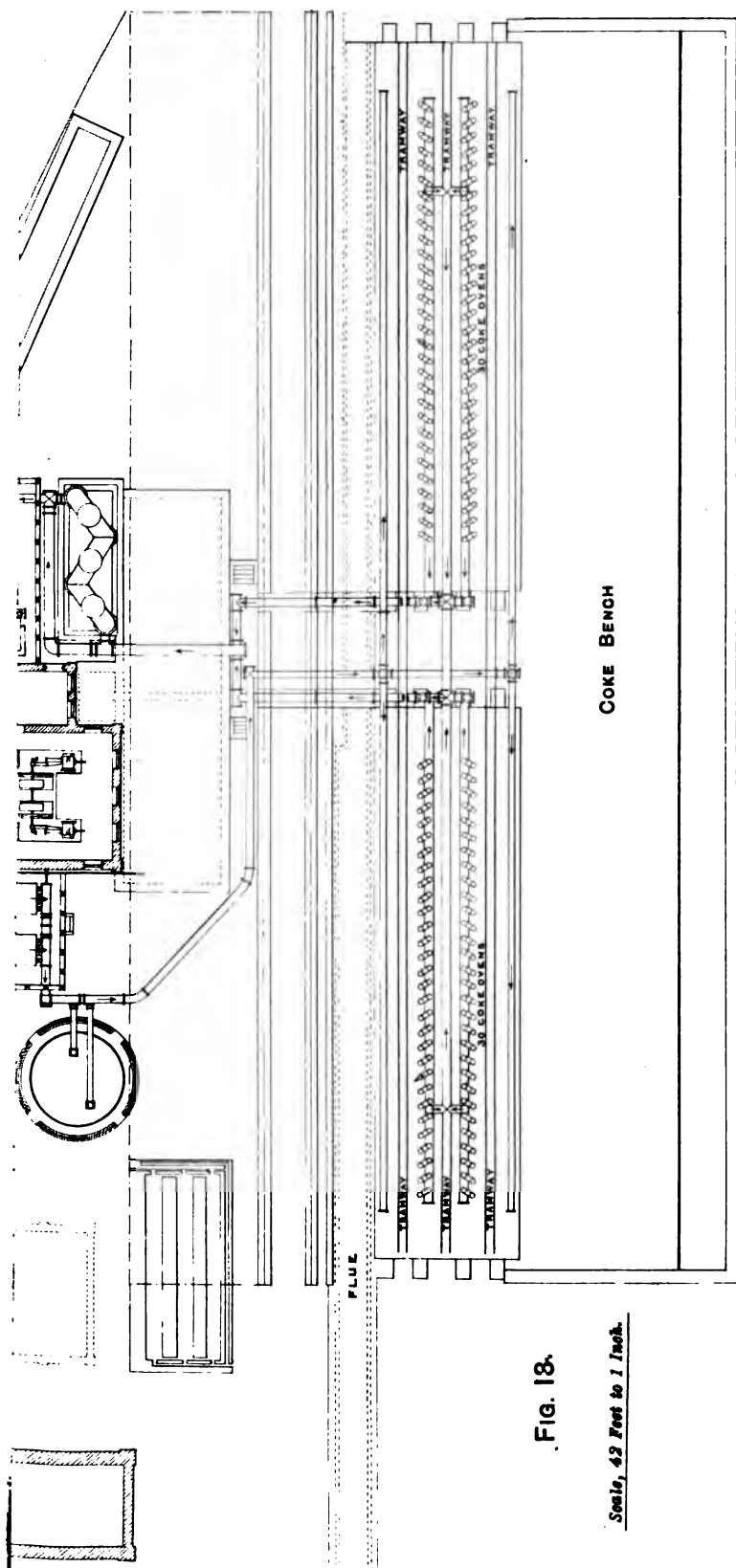


Fig. 18.

Scale, 42 Feet to 1 Inch.

RECOVERY OF CYANOGEN AND OTHER RESIDUAL PRODUCTS FROM THE WASTE GASES OF COKE-OVENS.

By HAROLD BONSER.

This paper contains a description of the Holmes scrubber and appliances for the extraction of ammonia and other residual products from the waste gases of coke-ovens; and it is more especially written in order to direct the attention of members to the extraction of cyanogen. In recent years a demand has arisen for various cyanides. Potassium or sodium cyanide possesses very active properties in dissolving metals, such as fine gold left in a state of fine division in tailings; and other methods of recovery are now dispensed with, owing to cyanide-extraction procuring a greater percentage of gold. Cyanides are also extensively employed as metallic solvents for gilding, electro-plating, etc. Ferrocyanides are manufactured for conversion into cyanides, and sulphocyanides are manufactured, not only for conversion into cyanides, but also for dying fabrics.

The Holmes scrubber-washer, described hereafter, is designed to carry out the purification of gas for commercial purposes, including the extraction of cyanogen, etc., and has the following advantages:—It removes every trace of the tar that may escape condensation in the condensers; it is self-cleaning, as the scrubbing discs never become clogged with tar, and its efficiency does not fall off with use; it produces liquor up to 30 ounces strength, and higher strengths can be obtained if desired; the quantity of washing-water is reduced to a minimum, with consequent avoidance of loss of valuable illuminants from the gas by their solution in the washing-water; the scrubbing is positive in its action, and there is no possibility of the gas escaping the action of the scrubbing-discs by short-circuiting; and whilst of small compass, the loss of gas-pressure is nominal, and since the plant does not clog, the gas-pressure does not rise with use.

The complete installation, which is shown in side elevation in Fig. 1, has been designed for practically applying the process for obtaining cyanides from waste gases, for which Mr. William Foulis obtained letters patent in 1892.

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RECOVERY OF CYANOGEN AND OTHER RESIDUAL PRODUCTS FROM THE WASTE GASES OF COKE-OVENS

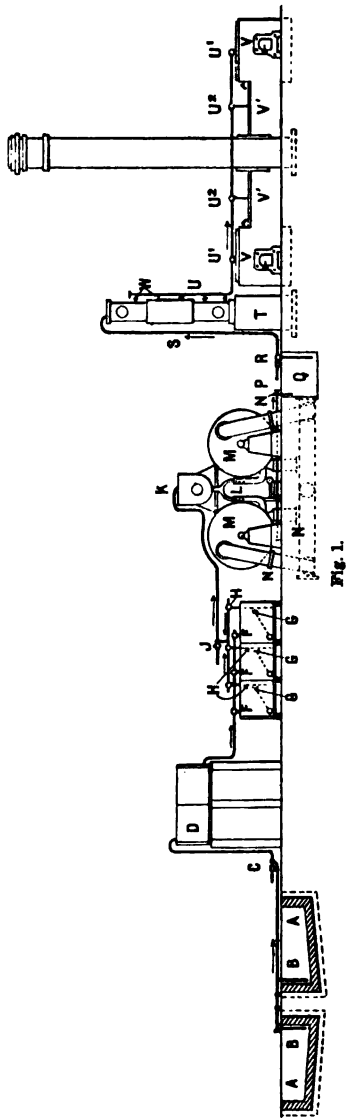
By HAROLD BOONER

This paper contains a description of the Holmes scrubber and appliances for the extraction of ammonia and other residual gases from the waste gases of coke-ovens; and it is more especially written to call the attention of members to the extent of waste. In recent years a demand has arisen for various grades of sodium cyanide possesses very active properties in leaching such as fine gold left in a state of fine division in sludge. Methods of recovery are now dispensed with, owing to the cost of procuring a greater percentage of gold. Cyanides are also employed as metallic solvents for gilding. Scarcely a ton of cyanides are manufactured for conversion into gold, and cyanides are manufactured, not only for conversion into gold, but also for drying fabrics.

The Holmes scrubber-washer, described here, is a simple and efficient out the purification of gas for commercial purposes, extracting and extraction of cyanogen, etc., and has the following advantages: it removes every trace of the tar that may be carried over from the condensers; it is self-cleaning, as the scrubbing discs are constantly clogged with tar, and its efficiency does not fall off at all; it provides liquor up to 30 ounces strength, and requires simply a few minutes if desired; the quantity of washing-water is reduced to a minimum with consequent avoidance of loss of valuable solvents from gas by their solution in the washing-water; the scrubbing is perfectly its action, and there is no possibility of the gas escaping the scrubbers the scrubbing-discs by design; and whilst of small construction, loss of gas-pressure is minimal, and hence the plant does not clog. This does not rise above the level of the gas.

The complete installation is shown in side elevation in Fig. 1, and the design of the scrubbing-disc is shown in side elevation in Fig. 2. The process for recovering cyanogen from the waste gases of coke-ovens, as described in this paper, was first patented by Mr. William Foulis in 1892.

Iron-liquor is prepared in the neutralizing-tanks, *A*, by, for example, dissolving scrap iron in hydrochloric acid. Pipes, *B*, are connected to a steam-injector or lifter, *C*, which effects the withdrawal of the iron-



liquor from the neutralizing-tanks, *A*, and discharges it into a storage-tank, *D*, from which it is drawn, as required, by the pipes, *E*, into precipitation-tanks, *F*, and is there mixed with alkaline carbonate (carbonate of soda), so that carbonate of iron is produced, which falls to the bottom of the tanks, *F*. The supernatant liquor is drawn off by means of jointed outlet-pipes, *G*, which follow the liquid as it descends in the tanks, *F*. Carbonate of soda is then added, with a sufficiency of water, to the carbonate of iron in the tanks, *F*, the liquor being preferably heated by means of a steam-coil, or by steam blown directly into the liquor. By means of pipes, *H*, and a steam-injector or lifter, *J*, the contents of the tanks, *F*, are delivered into a mixing-chamber, *K*, fitted with stirrers, consisting of paddles on a rotating shaft. The liquor, with the carbonate of iron in suspension, passes from the mixing chamber, *K*, by the pipes, *L*, into the horizontal scrubbers, *M*. The rotating parts in the scrubbers, *M*, and in the mixing-chamber, *K*, are driven by suitable gearing.

The gas from which the ammonia has been removed, and from which the cyanogen is to be separated, is passed through the scrubbers, *M*, by the pipes, *N*, passing from the said scrubbers by similar

pipes at the opposite end. The liquor from the scrubbers, *M*, which liquor contains the cyanogen removed from the gas in the form of sodium ferrocyanide, is pumped or run by the pipe, *P*, into a tank, *Q*, from which it may be pumped by the steam-injector or lifter, *R*, through the pipe, *S*, into

a settling-tower or tank, T , and thence is passed, by the pipes, U , into evaporating-pans, V V' , preferably arranged in duplicate, one pan, V' , of each pair being placed over the fire and the other pan, V , being placed directly over the fire, the thin liquor being passed into the latter pans, V , by the pipes, U' U' (by opening one or other of the upper valves, W), and the thicker liquor by the pipes, U^2 U^2 , by opening one or other of the lower valves U , into the former pans, V' , which are subjected to a lower temperature; or the liquor may be pumped directly from the tank, Q , into the pans V , and there evaporated to a certain extent, after which it is run into the pans, V' , where the liquor is completely evaporated.

The liquor from the scrubbers, when it has acquired sufficient strength, is drawn off, run into the evaporating-pans and evaporated down to a fluid paste, which is laid upon the drying-floors and allowed to dry, and is very shortly formed into a hard cake containing from 85 to 90 per cent. of ferrocyanide of soda, the impurities being carbonaceous matter and a small quantity of uncombined iron. It is not considered advisable to carry the process further; the cake is sold, and by a process not at all complicated it is converted into cyanide of sodium. On an average, 5 pounds of ferrocyanide of soda is obtained from every ton of coal, but that yield depends in a very great measure on the temperature at which the coal is coked or carbonized, and also upon the quality of the coal used.

Fig. 1 shows the complete plant, including the preparing of the saturated liquor for use in the scrubbers, but this process may be avoided by purchasing and employing materials already made for mixing and introduction into the mixing-chambers.

Cyanogen is recovered as a residual product in some Continental works on a somewhat large scale, whereas in Great Britain but little has been done.

There does not appear to be any doubt that the system of washing the gas in chemical solutions is the best one to adopt, particularly in gas-works conducted under the same conditions as those existing in London, and also where lime is used in the first purifiers by preference. About 80 per cent. of the cyanogen in the gas can be recovered by this method, in place of about 50 to 60 per cent. from "spent" oxide. It also possesses the advantage of being capable of producing ferrocyanides or sulphocyanides at will, according to the state of the market, and, from all points of view, it appears to afford the greatest margin of profit.

The last but not least point for consideration is the question of what is the probable profit to be gained? Mr. Lewis believes that cyanogen

can be profitably produced as a residual in gas or coke manufacture, for it must be borne in mind that the gas-maker produces cyanogen whether he wills it or not, and has only the cost of recovery to meet, while the chemical manufacturer has first of all to produce ferrocyanides or sulphocyanides by means of furnaces and other apparatus, involving a larger outlay for renewal of plant, followed by filtration and crystallizing as in a gas-works.

Supposing that the recovery of ferrocyanides be practised, it should yield (on an average) a profit of 9d. to 10d. per ton of coal carbonized, while sulphocyanides would probably produce from 1s. 2d. to 1s. 8d. per ton. These figures include cost of materials (with a liberal allowance for waste, if any), labour, fuel, packing, and depreciation, but are exclusive of interest on capital and general establishment charges. Favourable conditions of recovery, by reason of maximum yield, will increase the figures given by about 25 per cent. The demand for cyanides is still on the increase, and appears likely to continue, and will be probably met in the future largely from gas- and coke-works.

The present price of cyanide of potassium, as used in the Transvaal, is about 9d. per pound, including carriage and package, and would leave a profit of about 8d. per pound. Statistics showed that 6,000 tons had been used last year, and 7,500 tons had been produced in Germany. There is a steadily growing demand for cyanides, and the present price would allow of the profitable treating of tailings.

The PRESIDENT said that there could be no doubt whatever that a subject which would in the immediate future be most interesting to the mining engineer was how to obtain from coal some of those valuable products which had been hitherto allowed to go to waste. The recovery of cyanogen was one of the things which was expected to be of importance in the future, but it had not, so far as his information went, been very profitably or successfully operated hitherto. If all practical difficulties had been overcome, the Holmes recovery-plant certainly added another 6d. a ton to the value of the coal coked in bye-product retort-ovens. He had pleasure in moving a vote of thanks to Mr. Bonser for bringing the subject of his paper before them.

Mr. H. S. CHILDE (Wakefield) seconded the vote of thanks, and said that Mr. Bonser had shown the members that there was 8d. or 9d. a ton floating about in the atmosphere, and if they were only skilful enough and patient enough they might gather it into the balance-sheet. The whole of the cyanides used in the gold-fields of the world were produced in Germany; if they could only get into that field there might be for a limited trade some chance of living, but he supposed that they would find that all coals could not give such high results as 9d. a ton.

Mr. H. B. NASH (Clarke's Old Silkstone colliery) asked whether the action of the chemicals, passing through the scrubber, would affect the fibre of the brushes?

Mr. BONSER (Leeds) replied that the chemicals had no damaging effect on the brushes.

Mr. NASH remarked that if only 6,000 tons of cyanides were used last year, and if 7,500 tons were produced, the production was 1,500 tons in excess of the consumption and the price would speedily fall. The question was, could cyanides be produced at such a cost as would leave a profit, even if the selling price had a heavy fall? If cyanides dropped from 9d. to 4d. per lb., interest and standing charges might be more than the profit, and all advantages would be lost.

Mr. BONSER said that the Holmes recovery-apparatus could be seen working and producing good results at Brymbo, North Wales. The apparatus for a gas-works producing 5,000,000 cubic feet of gas from 50 tons of coal per day would cost about £1,500. It only required the attention of 1 ordinary workman.

The PRESIDENT said that many engineers had a stereotyped idea that when coal was coked, the only thing they had to recover was coke, whereas science had shown that they might not only recover coke, but other things of equal or even greater value. It would be a great pity if, because they might have been going on for a number of years at one thing, they should not, when they knew better, turn their attention and see if it were not possible to put something into the balance-sheets which they had been wasting. The development of the gold-mining industry was one of the most remarkable events of the time, and was due to the discovery that gold, in combination with other minerals which were perfectly intractable a few years ago, could by various processes, of which the cyanide process was the most important, be profitably treated. The desire of everyone to get gold if they possibly could, would always make

340 DISCUSSION—RECOVERY OF CYANOGEN, ETC., FROM COKE-OVENS.

gold-mining an exceedingly active industry wherever it could be done with advantage. He (the President) was pleased to hear that the recovery of cyanogen from coal-gas was a practical success at Brymbo. He liked to feel that the Midland Institute of Mining, Civil, and Mechanical Engineers was in the forefront if there was anything likely to become an important factor in the future, that they might be among the first to know about it, and take advantage of some of these unconsidered trifles which had enormous possibilities about them, and which they were inclined, perhaps, to allow to pass by.

The motion was carried, and the discussion adjourned.

Mr. F. COULTAS read the following paper on the "Geology of Deep car and its Surrounding Hills":—

GEOLOGY OF DEEPCAR AND ITS SURROUNDING HILLS.

By F. COULTAS.

Deepcar is situated at the junction of two of the valleys in the Pennine range, viz., the Don valley and the Little Don valley. The locality is, literally, a geologist's paradise. At every turn, he finds evidence of the tremendous natural forces that have been at work, both in deposition and denudation, through inconceivable ages, leaving a record of its history written in indelible characters in the exposed faces of the rocks and other strata which crop out to the surface, bed upon bed, in their order of superposition, while their inclination and dislocation record the great terrestrial disturbances that have taken place from time to time; and he observes, in the modest streams that wind their way along the bottom of the valleys, the representatives of the principal agents that have performed the gigantic task of denuding strata, thousands of feet in thickness, from off the higher hills, and carving out their present valleys with the process.

The valley itself is so deep and narrow that it almost forms a gorge. Taking the junction of the rivers as a central point, in the short distance of 4,200 feet the surrounding hills reach an altitude of 600 feet on the south-western side, 500 feet on the northern side, and 525 feet on the eastern side. About 1,000 feet northward of the junction of the rivers, and within their contained angle, is an alluvial cone about 600 feet wide at its base and 30 feet deep at its northern side where it adjoins the solid strata, the face being nearly vertical. It would appear that a torrent had descended into the valley by this course, eroding the strata in its descent. As the higher regions were denuded and the stream lost a portion of its energy the detritus brought down was deposited in the trough previously eroded, until it became refilled with alluvium. The deposit consists of shales, binds, and grit, interspersed with boulders of gritty sandstone.

The strata is very much dislocated by faults, which traverse the locality in all directions. In some cases, several faults are found within a short distance of each other, having their throw in opposite directions, and consequently forming a trough in the faulted strata. It is evident that these faults, being inclined towards each other, must meet at a point in the strata below, when the multiple of faults will either intersect each

other and diverge in opposite directions, or otherwise be reduced to one fault (the latter being the most probable issue). It will also be observed that faults of this description produce most favourable conditions for denudation by splintering the strata, and causing a depression at the surface (running parallel with the faults) of greater or lesser extent, according to the amount of throw of the opposite faults, but sufficient, in any case, to give direction to the flow of a stream of water.

The preceding observations lead to the following deductions, viz., (1) that in the thousands of feet of denuded strata which overlaid the present surface, these sets of faults would be far more numerous than in the remaining strata, and that only one fault, or perhaps none at all, is left to mark their location; (2) that the direction of the present valleys was due, in the first instance, to the depression caused by such sets of faults at the surface of the denuded strata, thus giving definite direction to the flow of water; and (3) that denudation has been greatly facilitated by the faulted condition of the strata.

On referring to Fig. 1 (Plate XVIII.) some of the faults will be seen in plan. The fault which enters the southern side of the plan, and runs in a north-westerly direction, passing through Allman Well Hill and Round Hill, in Townend Common, has a throw of about 114 feet up to the south: throwing out the gannister coal-seam which is found in the strata on its northern side. The highest coal-seam found in the strata on the southern side of this fault is the clay coal-seam, which crops out to the surface at a very short distance from the fault. The coking coal-seam crops out in Bank Lane, and the pot-clay and Millstone Grit crop out about 350 feet lower down the southern side of the hill. On the northern side of the fault are three smaller faults (Fig. 1, Plate XVIII.) The fault shown to be down to south, $1\frac{1}{2}$ feet, becomes greater as it runs eastward, forming a trough in the strata with the other faults.

Branching out of the 114 feet fault, at a point near to Round Hill, is another large fault throwing up to the south, which takes a north-easterly direction, passing through Deepcar railway-station, and forward through Wortley. Its throw is 120 feet at Deepcar, and the fault can be seen in the cutting at Deepcar railway-station.

One interesting feature of the above faults is the change in thickness and quality of the coking coal-seam in their vicinity. On the northern side, the coking coal-seam is of good quality, its section being generally 2 feet, but thinning down to 10 or 12 inches as it approaches the faults; while on the southern side it continues from 10 to 12 inches in thickness and is of inferior quality.

The fault which passes through Ellen Cliffe, in a northerly direction, is shown on sheet cclxxxii., S.W., of the Geological Survey map of Yorkshire (West Riding) to be a downthrow of 18 feet to the east. This, however, is an error, as the fault has an actual downthrow of 19 feet to the west. Adjacent to it are six lesser faults, three of them down to the west of 6 inches, 1 foot 8 inches, and 7 feet respectively, and three down to the east of 2 feet, 1 foot 3 inches, and 5 feet respectively, forming a trough in the faulted strata.

Faults also run parallel with the Don and Little Don rivers.

The full dip of the measures is to the north-east and varies from 1 in 15 on the southern side to 1 in 6 on the northern side of the valley. The several seams of coal and fire-clay crop out along the hill-sides, and are won by means of drifts.

The minerals worked in the Deepcar district are :—

(1) *The White Carr Fire-clay*, which lies below the Halifax hard coal-band, has the following section :—

					FT.	IN.
COAL , inferior	...	...	...	...	0	8
Black bat	...	...	...	...	0	6
Fire-clay	...	...	...	...	3	0

The fire-clay is used in the manufacture of refractory goods, sanitary tubes, enamelled ware, etc. The seam crops out along the northern side of the Little Don valley, a portion of it having been denuded where the alluvial deposit is found, previously described. It may also be seen in the railway-cutting, on the northern side of the fault, in Deepcar railway-station. It is not found in the strata on the southern side of the valley.

The bed of rocks, which constitutes the wellknown Wharnccliffe Crag, lies almost directly beneath the White Carr clay, particulars of which, and other intervening strata, are shown in Appendix A.

(2) *The Gannister or Halifax Hard Coal-seam* has its position in the strata 143 feet below the White Carr clay. The section and quality of the coal is variable, and it contains irregular bands of iron pyrites, which occasionally reach a thickness of 16 inches. The coal crops out to the surface on both sides of the valley. The floor of the coal-seam consists of a very hard gannister rock varying in thickness from 6 inches to 3 feet. It is nearly pure silica, and it is so hard that the most powerful explosives are required in blasting it. It is used in the manufacture of silica bricks, etc.

The average section of the coal-seam and gannister may be taken as follows :—

						Ft.	In.
COAL	...	...	...	...	...	2	0
Gannister	...	...	...	...	...	1	6
Fire-clay, inferior	...	...	...	...	...	4	0

(8) *Clay Coal, Middle Band, or Halifax Soft Coal Band.*—This seam of coal lies 70 feet below the gannister coal-seam. It is only worked to a very limited extent, as its bed of under-clay is usually unsuitable for refractory purposes, and is also very variable, both in quality and thickness. At Carr Head the clay is absent, and the coal is of double thickness, with a dirt parting (6 inches thick) between, as follows :—

						Ft.	In.
COAL, inferior	...	...	...	...	...	1	0
Dirt	...	...	...	...	...	0	6
COAL, inferior	...	...	...	...	...	1	0

The clay coal-seam crops out at several places on each side of the valley, and its average section may be taken as follows :—

						Ft.	In.	Ft.	In.
COAL, "branch"	varies from	0	0	to	0	4			
COAL, "softs"	,,	0	7	,,	0	10			
Gannister, inferior	,,	0	0	,,	0	8			
Fire-clay, variable	,,	0	8	,,	2	9			

(4) *The Coking or Halifax Soft Coal.*—This coal-seam lies 72 feet below the clay coal-seam. The coal is of good quality, with the exception named in a former part of the paper. Its average section is 2 feet, and it also crops out at the surface along the sides of the valleys.

(5) *The Pot Clay.*—Resting upon the Millstone Grit, 146 feet below the coking coal-seam, is the pot clay. Its average section is about 4 feet 6 inches. The clay, where it lies near the surface, is of very good quality for all refractory purposes. Above the clay is a thin band of coal, varying from 1 to 4 inches in thickness.

The intervening rocks are very thickly bedded in some places, and are quarried for the amount of silica which they contain, and also for flagstones, etc.

The principal fossils observed by the writer are :—Brachiopods; Cephalopods (*Goniatites*); Lamellibranchs (*Anthracomya Adamsii*); *Calamites*, *Sigillaria*, *Stigmaria*, and *Lepidodendron*.

From the nature of the predominating minerals, Deepcar is, essentially, a gannister and fire-clay district; but the methods of working these minerals, and the trying conditions under which gannister has to be worked and treated, do not come within the scope of this paper.

It is, however, worth noting that the officially recorded output of gannister in Great Britain and Ireland expanded from 1,011 tons in 1878 to 114,627 tons in 1895. Of the latter quantity 86,841 tons (or a little over three-quarters of the whole) was produced in the Yorkshire district, and Deepcar can fairly claim to be the centre of the gannister industry.

APPENDIX A.—SECTION OF THE STRATA ON THE NORTH SIDE OF THE LITTLE DON RIVER.

No.	Description of Strata.	Thick- ness of Strata. Ft. In.	Depth from Surface. Ft. In.	No.	Description of Strata.	Thick- ness of Strata. Ft. In.	Depth from Surface. Ft. In.
1	Shale, containing bands of iron- stone ...	18 0	18 0	16	Flagstone, good	6 0	92 7
<i>Halifax Hard Band</i>				17	Stone bind ...	5 0	97 7
<i>Coal-seam—</i>				18	Brown bind and shale, containing irregular bands of ironstone ...	65 0	162 7
2	COAL, inferior	0 8	18 8	<i>Gannister or Halifax</i>			
3	Black bat ...	0 6	19 2	<i>Hard Coal-seam</i>			
4	White Carr fire- clay, variable in thickness ...	3 0	22 2	19	COAL ...	2 0	164 7
5	Light bind ...	5 0	27 2	20	Gannister, variable in thickness ...	1 6	166 1
6	Strong bind ...	3 0	30 2	21	Fire-clay, inferior	4 0	170 1
7	Stone bind ...	7 0	37 2	22	Blue bind ...	14 0	184 1
<i>Wharnclife Rock—</i>				23	Dark bind ...	25 0	209 1
8	Closely-grained sandstone ...	16 0	53 2	24	Fire-stone ...	24 0	233 1
9	Stone bind ...	9 0	62 2	25	Shale ...	1 0	234 1
10	Strong sand- stone ...	10 4	72 6	<i>Clay Coal, Middle Band, or Halifax Soft Coal</i>			
11	Stone bind ...	3 0	75 6	<i>Band—</i>			
12	Strong sand- stone ...	3 11	79 5	26	COAL ...	1 1	235 2
13	Stone bind ...	0 7	80 0	27	Fire-clay, variable in thickness ...	2 6	237 8
14	Flagstone, good	3 0	83 0	28	Bind ...	2 0	239 8
15	Very soft yel- low stone ...	3 7	86 7	29	Stone bind ...	3 0	242 8

APPENDIX B.—SECTION OF THE STRATA ON THE SOUTH SIDE OF THE LITTLE DON RIVER, AT CARR HEAD.

No.	Description of Strata.	Thick- ness of Strata. Ft. In.	Depth from Surface. Ft. In.
<i>Clay Coal-seam—</i>			
1	COAL, inferior ...	1 0	1 0
2	Dirt ...	0 6	1 6
3	COAL... ...	1 0	2 6
4	Closely-grained sandstone ...	39 0	41 6
5	Binds and shale ...	33 0	74 6
<i>Coking or Halifax Soft Coal-seam—</i>			
6	COAL ...	2 0	76 6

APPENDIX C.—SECTION OF THE STRATA IN A SINKING AT ROYD.

No.	Description of Strata.	Thick- ness of Strata.		Depth from Surface.		No.	Description of Strata.	Thick- ness of Strata.		Depth from Surface.	
		Ft.	In.	Ft.	In.			Ft.	In.	Ft.	In.
1	Shale ...	12	0	12	0	11	Shale ...	6	0	108	0
2	Rock ...	15	0	27	0	<i>Coking or Halifax Soft</i>					
3	Shale ...	3	0	30	0	<i>Coal-seam—</i>					
<i>Clay Coal-seam—</i>						12	COAL ...	2	3	110.	3
4	COAL ...	1	0	31	0	13	Rocks and binds	102	0	212	3
5	Fire-clay...	2	0	33	0	14	Grey shale	25	0	237	3
6	Rock ...	4	6	37	6	15	Black shale	15	0	252	3
7	Shale ...	18	0	55	6	16	Shale ...	4	3	256	6
8	Rock ...	18	0	73	6	17	COAL ...	0	3	256	9
9	Shale ...	18	0	91	6	18	Pot clay ...	4	6	261	3
10	Bind ...	10	6	102	0	<i>Millstone Grit.</i>					

The PRESIDENT remarked that the Deepcar district was one with which he was fairly familiar, and there were one or two questions of great interest. It had always seemed to him that the erosion of valleys must be largely affected by dislocations of the strata under which the weakest line would suffer most from the operation of atmospheric causes, from the effects of rain and frost, and all the other forces which caused destruction of rocks. The Little Don valley, with a fault running right down it, seemed to imply a line of weakness along the line of that fault, causing a narrow precipitous valley formed by the wash of water during a long period. At Olough Dyke, there was a fault running along the line of the valley. They also had a fault running down the line of the main Don valley. Although he did not for one moment wish to make the wide statement that faults and valleys invariably ran together it was interesting to note that where Coal-measures were the uppermost formation they often found that the lines of valleys might be explained by the trend of particular faults. He had much pleasure in moving a vote of thanks to Mr. Coultas for his interesting paper.

Mr. J. NEVIN (Mirfield), in seconding the motion, said Mr. Coultas stated that the measures at Deepcar were much thicker than in the Halifax neighbourhood, but judging from the information he had given the members there was not much difference. There seemed to be a difference between the hard and soft coal-seams of 120 to 150 feet, near Halifax it was 90 to 120 feet.

Geological map of the Deepcar and Townend area, showing coal seams, railways, and local landmarks. The map includes labels for various coal seams (e.g., Carr Head, Bannister, Halifax), railways (e.g., Sheffield & Lincolnshire, Great Northern), and landmarks (e.g., Deepcar, Townend, Royd). A scale bar indicates 1,488 feet to 1 inch.

----- FAULTS

----- $\frac{1}{2}$ INCH AN ARROW IS PLACED ON THE DOWNCAST
SIDE OF FAULTS, AND THE AMOUNT
OF THROW IS WRITTEN IN FEET AND
INCHES

----- ² OUTDROPS OF COAL-SEAMS AND FIRE-CLAY
BEDS

----- OUTDROPS, WHERE UNCERTAIN, THUS

And^{rs} Reid & Comp^{rs} L^{td} Newcastle on Tyne

Mr. H. HINCHLIFFE (Bullhouse colliery) remarked that in the Halifax district there was 105 feet of strata between the Halifax hard coal band and the Halifax hard coal-seam, but in the Deepcar district there was about 150 feet. Further west, the thickness was over 150 feet. He had always considered that there was a greater thickness of strata between these coal-seams near Deepcar than there was in the Halifax district.

Mr. COULTAS said that there was a gradual development of thickness between Halifax, Bradford, and South Yorkshire.

Mr. NEVIN enquired whether the gannister beds had been proved to the south of Sheffield.

Mr. COULTAS stated that the gannister beds were found at Alton colliery, near Ashover.*

The vote was agreed to, and the discussion adjourned.

* *Trans. Fed. Inst.*, vol. x., page 491.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND
MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
JUNE 12TH, 1897.

MR. GEORGE MAY, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the Special General Meeting, held on April 10th, 1897.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on May 29th and that day.

The SECRETARY read the Balloting List as prepared by the Council for the election of officers for the year 1897-98.

The following gentlemen were elected, having been previously nominated :—

MEMBERS—

- Mr. ISAAC BARRASS ATKINSON, Mining Engineer, Lynwood, Egremont, Carnforth.
Mr. EDWARD TRENHOLM BAILEY, Mining Engineer, c/o Union Bank of Australia, Coolgardie, Western Australia. .
Mr. ALBERT WILLIAMS DAW, Mining Engineer, 11, Queen Victoria Street, London, E.C.
Mr. JOHN WILLIAM FRYAR, Mining Engineer, Jobs Hill, Crook, near Darlington.
Mr. CHRISTOPHER GOLDSWORTHY, Mine Manager, Coolgardie, Western Australia.
Mr. JOHN JAMES, Mining Engineer, c/o Mrs. Corkhill, 13, Gladys Road, West Hampstead, London, N.W.
Mr. THOMAS JONES, Mining and Quarry Engineer, and Surveyor, 1, Princes Street, Great George Street, London, S.W.

- Mr. AUSTIN KIRKUP, Manager, Newbottle Colliery, Bunker Hill, near Fence Houses.
Mr. ALFRED ANDREW LOCKWOOD, Mining Engineer and Assayer, 119, Victoria Arcade, Auckland, New Zealand.
Mr. THOMAS PASCOE, Mining Manager, c/o Bank of Australasia, London.
Mr. WILLIAM BATTLE PHILLIPS, Consulting Chemist and Engineer, Birmingham, Alabama, United States of America.
Mr. WILLIAM THOMAS SAUNDERS, Colliery Manager, Ivydene, West Cross, near Swansea, R.S.O.
Mr. EDWARD STABLES, Mining Engineer, Coolgardie, Western Australia.
Mr. SAMUEL TULIP, Mechanical Engineer, Bunker Hill, Fence Houses.
Mr. PRESCOTT UPTON, Assoc. M. Inst. C.E., Surveyor, City and Suburban Gold Mining Company, P.O. Box 1026, Johannesburg, Transvaal, South Africa.
Mr. ALFRED EDWARD WEBSTER, Mining Engineer, Wigan Coal and Iron Company, Limited, Wigan.

ASSOCIATE MEMBERS—

- Mr. E. HERBERT BECKE, Coolgardie, Western Australia.
Mr. DAVID HARRIS, Cymmer Colliery, near Pontypridd.
Mr. THOMAS H. LEGGETT, c/o Messrs. S. Neumann and Company, P.O. Box 485, Johannesburg, Transvaal.
Mr. P. MARSHALL, College and Grammar School, Auckland, New Zealand.
Mr. ERNEST WILLIAM TATTLE, Taupiri Extended Coal Mining Company, Limited, Mine Manager's Office, Waikato, Auckland, New Zealand.
Mr. HENRY B. WARREN, Vancouver, British Columbia.
Mr. ALFRED ERNEST WESENCRAFT, Clyde Gold Mines, Limited, Coolgardie, Western Australia.
Mr. THOMAS WHITEHEAD, Brindle Lodge, near Preston, Lancashire.
Mr. ARCHIBALD LAWRENCE WILSON, John Bull Gold Mining Company, Limited, Ravenswood, Queensland.

ASSOCIATE—

- Mr. WILLIAM HANDYSIDE, Jun., Overman, Ravensworth Avenue, Dunston-upon-Tyne.

STUDENTS—

- Mr. BERNARD JAEGER, Mining Pupil, Holywell Hall, Durham.
Mr. JOHN ALEXANDER PETERKIN, Engineer's Apprentice, 13, Swinley Road, Wigan.
Mr. THOMAS SNOWDON, Jun., Mining Student, Oakwood, Cockfield, R.S.O.

Dr. P. P. BEDSON gave a demonstration with the "Shaw Gas-tester."

SHAW GAS-TESTER.

By DR. P. P. BEDSON.

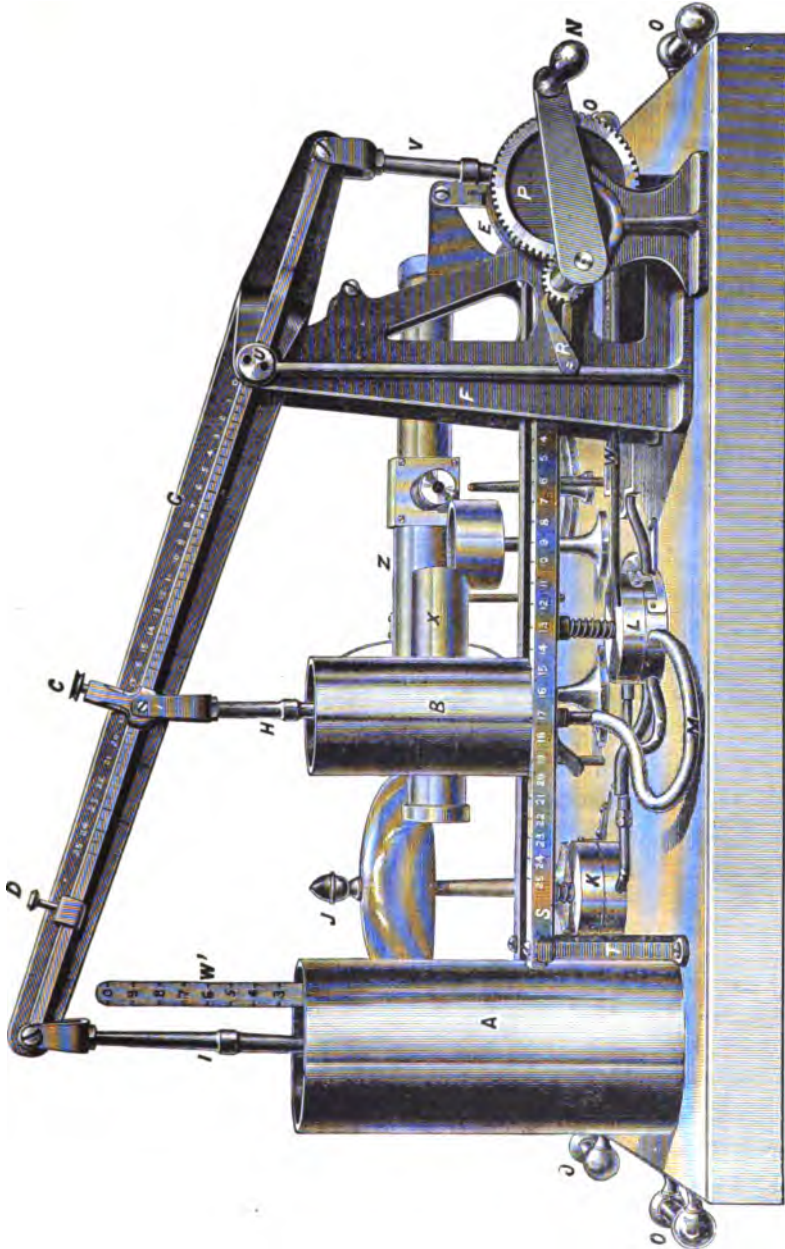
The Shaw gas-tester had been described a few years ago in the *Transactions* of The Federated Institution of Mining Engineers;* it would not, therefore, be necessary for him to give a detailed description of the apparatus. It was one of a type of many others introduced within recent years to abolish skilled labour, and was intended to do away with the chemist in connexion with the determination of gas in the air of a mine.

Briefly, the apparatus consists of two cylinders provided with pistons, and with the upward stroke, into one cylinder *A*, air was drawn through an aperture, in a certain position of the valve *K*, and through another aperture in connexion with the same valve, gas was drawn into the shorter cylinder *B*, and in that way the two cylinders were filled, one with air and the other with gas. With the down stroke of the pistons of the cylinders, the gas from the cylinder *B* and the air from cylinder *A* were pressed out, mixed together, and conveyed by pipes to the mixer (not shown in the diagram) into the igniting-chamber *Z*, and so were blown through the burning gas-jet. If an explosive mixture was blown through the flame ignition took place, which moved the piston-head and rang the bell, *J*.

He would now show them the actual working with Newcastle coal-gas as a standard, contained in an indiarubber bag, attached by a tube to the nozzle labelled gas. When he raised the pump-lever, air was drawn into the cylinder *A*, and gas from the bag into the cylinder *B*. When the pump-lever was depressed, air and gas were blown into the flame without any appreciable effect. The gas-cylinder now stood at $7\frac{1}{2}$ per cent., and he must move it along the graduated pump-level until it got to the point at which the ignition of the mixed gases would ring the bell, *J*. He must now establish the ringing-line; he would work backwards from 11 per cent. until they reached the point where it would only just ring the bell (demonstrated at $10\frac{1}{2}$, 10, $9\frac{1}{2}$, 9, and $8\frac{1}{2}$ per cent.). At $8\frac{1}{2}$ there was an ignition, but not strong enough to ring the bell; he would move the

* Vol. viii., page 161.

gas-cylinder back to 9, and show again that it rang at 9 per cent. (demonstrated again at 9 per cent.). Having got to this stage, and having



obtained the ringing-line for ordinary Newcastle coal-gas, he placed the bolt *D* in position, which served to remind them what was the ringing-line.

If they wanted to examine a sample of air and gas, whose exact gas contents they wished to determine, they could do that first of all by attaching the gas-bag to the air-cylinder, and seeing whether they could get any ringing-line with it. If they failed to do that, the method to be adopted would be to attach the gas-bag to the air-cylinder nozzle, and then attach to the gas-cylinder nozzle the standard gas. Then if the air, being drawn in, contained say 1 per cent. of gas with that mixture of gas and air they were examining, instead of having the cylinder at 9 per cent. they would have it at 8 per cent., the difference between these two positions thus giving the percentage of gas in the sample.

Now instead of using this gas he would use a 3 per cent. mixture of gas and air, which he had just made, and he would use the apparatus to test its composition. After several trials, however, at $6\frac{1}{2}$ per cent. the explosion was sufficient to ring the bell. This showed that there was $2\frac{1}{2}$ per cent. of gas, being the difference between $6\frac{1}{2}$ and 9 per cent., and it was perhaps as near as a chemist could get, but not so near as the machine was supposed to show them.

Under the circumstances, however, he might record it as a satisfactory test, and he hoped that they understood the mode of procedure. They first established with a known gas a standard ringing-line, then they had to examine a mixture containing a small percentage of combustible gas that was to be used instead of air and raise its gas contents till they got to the ringing-line. Then the difference between the standard-line and that given by the mixture, was the gas content of the sample tested.

If the sample of air contained a high percentage of gas, say 10 or 11 per cent., the standard gas would be disconnected, and the sample air would be attached instead. In some cases, the sample might require dilution with air before being tested.

The instrument could also be used to determine the percentage of carbon dioxide in air. For this purpose, the mixture was deflected to pass through a tube containing lime-water, and from the milkiness they could determine the proportion of carbon dioxide in the air.

He would draw especial attention to the necessity for care in the size of the flame. If the flame was too high, it came to the hollow part of the tube and it was possible to draw in a small quantity of gas into the igniting-chamber, sufficient to produce an explosion of itself, so that unless they were very careful they might apparently show that ordinary air contained combustible gas.

The PRESIDENT remarked that the Shaw gas-tester appeared to be a useful instrument and very much in advance of other apparatus which had been exhibited for testing mixtures of air and fire-damp. A mechanical means of testing mixtures of air and fire-damp could be usefully applied at coal-mines. Their best thanks were due to Prof. Bedson, and he had pleasure in proposing a vote of thanks to him for his demonstration.

Mr. HENRY LAWRENCE (Durham) asked whether the Shaw gas-tester effected any saving of time as compared with the ordinary chemical methods of gas analysis?

Dr. BEDSON said that with this machine he could arrive at an approximate result more rapidly than with a chemical appliance. With chemical appliances, of course, they would require a trained chemist and apparatus, and a special room for the purpose. The machine gave somewhat accurate results. The machine could not make an analysis, it could only determine what percentage of inflammable gas was present in the air.

Prof. H. LOUIS (Newcastle-upon-Tyne) said that there were many sources of inaccuracy about the Shaw machine. It appeared that they had to compare the gas which they had in the pit with a standard gas. Now, unless that standard gas was of the same composition as the gas in the mine, he did not see how they could make an exact comparison; he did not see how they could determine the amount of fire-damp in a pit-gas mixture unless there was in the same pit a blower from which they could get a quantity of pure pit-gas sufficient to establish a ringing-line. Would not changes of temperature affect the ringing-line? The rate at which the crank of the machine was driven might also make a difference in the results. There seemed to him to be many possibilities of inaccuracies, and he did not think that the members should receive the impression that it was a proved and reliable machine for the purpose of determining the percentage of gas in the air of the mine, and more especially when placed in unskilled hands.

Dr. BEDSON, replying to Prof. Louis, thought that they could actually compare pit-gas or fire-damp with hydrogen or coal-gas. If hydrogen was the standard test, they would establish a certain ringing-line for hydrogen. If, instead of mixing air with hydrogen, they mixed air containing a little fire-damp, a smaller quantity of hydrogen would be required to produce the mixture which would ring the gong; and the difference between the two percentages would indicate the percentage of inflammable

gas, and the result would be accurate for all practical purposes. He had only compared hydrogen with hydrogen, fire-damp with fire-damp, and coal-gas with coal-gas.

Prof. Louis' remark about the temperature of the apparatus was correct, and the apparatus had to become heated by several ignitions before starting the actual experiments.

When he first worked with the gas-tester, he found considerable difficulty owing to the height of the flame. If the flame were not of the proper height, as he had said before, gas would be drawn into the ignition-chamber *Z*. When he first tried the machine he got a ringing-line for marsh-gas at a certain point; by working the machine in a slightly different manner he got the ringing-line down to nearly zero, and that was due to the fact that the flame was not properly regulated. Like all other machines, it had to be carefully worked, but he should certainly prefer the results obtained by analysis to those given by the machine. He proposed to further investigate the Shaw gas-tester and to examine experimentally the points raised by Prof. Louis, and would submit the results to a future meeting.

Mr. M. WALTON BROWN suggested that the difference, $2\frac{1}{2}$ per cent., between 9 and $6\frac{1}{2}$ per cent. did not exactly represent the actual percentage of gas. Dr. Bedson had formed a 3 per cent. mixture, the ringing-line was 9 per cent., and the bell was rung when the gas cylinder was set at $6\frac{1}{2}$ per cent. By calculation, he (Mr. Walton Brown) found from these results that the actual mixture contained $(6\frac{1}{2} + 93\frac{1}{2} \times 2.68 \div 100 =)$ 9 per cent. or a ringing-line of 9 per cent. The 3 per cent. mixture was found to really contain 2.68 per cent.; and there was, consequently, an instrumental error of $(3.00 - 2.68 =)$ 0.32 per cent., which suggested that the results obtained could be relied upon to $\frac{1}{2}$ per cent.

DISCUSSION UPON MR. W. GALLOWAY'S PAPER ON "A COMPOUND WINDING-ENGINE."*

Mr. J. B. SIMPSON stated that the compound winding-engine at North Elswick colliery had not been found quite satisfactory, but he thought that this was due to there being only three instead of four cylinders. Increased cost was incurred for the engine, there were more valves to keep in order, and he rather doubted whether a compound engine was worth erecting for winding purposes.

* *Trans. Fed. Inst.*, vol. xi., page 207.

Mr. C. C. LEACH remarked that the governor would not act easily on the steam-admission valve if the engine had more than one cylinder. Consequently, the steam could not be cut off automatically, instantaneously, and variably with a simple action.

The PRESIDENT said there was no doubt that compound engines would be improved until they could be economically used for winding. At present great advantages were obtained from ordinary high pressure winding-engines by applying automatic cut-off gear.

The following paper by Mr. W. Fryar on "The Mineral Resources of the Colony of Queensland," was taken as read :—

THE MINERAL RESOURCES OF THE COLONY OF QUEENSLAND.

BY WILLIAM FRYAR, INSPECTOR OF MINES.

After a period of unusual excitement touching the extraordinary discoveries of the precious metal in the comparatively unknown colony of Western Australia, and the still more extraordinary value of diamonds laid bare in the wilds of South Africa, it would seem futile to attempt to draw attention to the matter-of-fact, plodding, and prosaic producers of that metal, located diagonally opposite the settled corner of the western colony, in the north-eastern corner of the great fifth continent: partly, perhaps, because the production of gold in that region is not a new thing; partly because her wealth of wool, of beef, and of sugar overshadows her production of the precious metal, and partly because she is entirely devoid of the excitement arising "where crouching tigers wait their hapless prey, or savage men more murderous still than they;" for whatever dangers may have existed from the latter cause in times gone by, they have now disappeared, and the danger is rather to the savage than to those who have usurped his territory, whilst that from the beasts of the forest, plain, or jungle, never existed.

The whereabouts of Queensland can now be found in most maps, although curiously enough the writer remembers, when, within a decade of the present time of writing, journeying between the mother land and the colony in question after a visit to the old country, a very elegantly got up work, which would cost many thousands of pounds to produce, and which had then been but recently issued from the press, lay on the cabin table of the outward bound steamer, a vessel whose especial duty was to connect Queensland with the old country. The book contained some reference to Queensland certainly, and mentioned her coals, implying that steamers could load supplies of that very necessary commodity in her ports, but did not say a word about her production of gold, which had then for some years amounted to more than £1,000,000 per annum, and far exceeded in value her production of all other minerals put together.

As similar evidences of defective information are frequently observed, the writer opines that a paper on the mineral resources of Queensland will not be unacceptable to the members.

To the readers of Australian history, it will be known that Queensland is the most recently settled of the Australian colonies, having been, at the time of the discovery of gold in Victoria and New South Wales in 1851, a small outlying settlement of the mother colony, with a population of considerably under 10,000, who were chiefly engaged in or depended on the then staple industry of wool-growing. The late Rev. Dr. Lang had then but recently made its prospects known in Great Britain, and had been the means of sending out three ships with passengers to settle in the Moreton Bay country in 1849, thus giving an impetus to the moral and material progress of the district, which will not be forgotten for many generations.

In 1859, the district was erected into a separate colony under the governorship of his Excellency Sir George Ferguson-Bowen. But at that time very little progress had been made in the development of the mineral resources. A somewhat disastrous rush had been made in 1858 to a discovery of alluvial gold, and a little coal had been worked prior to our establishment as a separate colony, but that was all. The influx of population, however, and the consequent increase of geographical knowledge soon became the means of the discovery of mineral wealth, particularly of gold, although it was not until October, 1867, that the mining industry became of much importance, when the discovery of gold at Gympie was effected. It is a singular illustration of what may happen when the faculties are aroused and attention directed to a certain matter, that in 1851, the year of the discovery of gold in New South Wales and Victoria, a passing traveller between Maryborough and Brisbane found gold at Gympie, the discovery being mentioned in the *Moreton Bay Courier* at the time, but it was not then considered sufficiently promising to induce persistent effort, and remained among our latent resources for a further period of sixteen years. It is unnecessary to write a history of its development: the discovery gave the colony at once a position of importance among the gold-producers of the world, which position it has maintained, until at the present time it disputes, in friendly rivalry with the colony of Victoria, the supremacy of the Australian colonies in the production of the precious metal, having on several occasions during recent years exceeded that, or any of the colonies, in the amount of its production. The discovery at Gympie

doubtless gave an impetus to prospecting operations over the whole colony, and various discoveries of silver, tin, copper, lead, iron, and the earthy minerals were made in various portions of the colony, whilst precious stones also now figure in the list of exports.

It is among the difficulties, however, of industry in a large and sparsely populated territory that, unless the lodes or veins of mineral matter be greatly more prolific of the valuable material than is usual in older countries, it cannot be worked to advantage. The absence of navigable waters, railways, and even ordinary roads and bridges, the consequent high price of material, and difficulties of transit, militate against successful industrial production.

These difficulties, however, are fast disappearing with the occupation and settlement of the country, and a longer line of railway in proportion to our population than is possessed by any other people gives evidence that we are not deficient in the enterprise which will facilitate the discovery and development of our mineral resources.

The more important of the discoveries referred to were those of gold at the Etheridge river, which is now the largest gold-field in Queensland, and at Hodgkinson, the Gilbert river, and Ravenswood, from 1868 to 1870; tin at Stanthorpe, and gold at Charters Towers, in 1872; the alluvial gold of the Palmer river in the following year; and in 1883 the astounding discovery of gold at Mount Morgan, where it had lain within about 20 miles of the second town in the colony, a mountain of auriferous material exposed to the eye, hand, or foot, of the passer-by, without arousing a suspicion that he was treading under foot millions of pounds sterling worth of the precious material. And this discovery was followed by others, at Croydon in the far north near the shores of the Gulf of Carpentaria, and at Eidsvold in the south. There are other mining-fields besides those above enumerated; that at Clermont, amongst the earliest discovered in the colony has recently been the scene of considerable activity owing to a further discovery of alluvial gold in its watercourses and the riparian plateaux. Other small gold-fields in the central district continue to supplement the production of Mount Morgan, the chief seat of the industry in that division of the colony; whilst in the south, the Warwick and the Burnett gold-fields add to the output, and in the north, Mareeba, Towalla, and the Russell river contribute their quota to the gross production of the precious metal.

Touching the inferior metals, the writer has already mentioned the discovery of tin at Stanthorpe in 1872. This township is situated in the extreme south of the colony; but some six or seven years sub-

sequently further discoveries of the same mineral were made in the Northern Division, at the Barron river, and at various points in the district now known as Tinaroo, in the Wild, Dry, Tate, and Walsh rivers. In 1880, lode-tin was discovered at Herberton, and it was found that tin-lodes were distributed over a very large area of country, in comparison with which the tin-bearing country of Devon and Cornwall is of the most insignificant dimensions. The working of tin-lodes, however, is not so satisfactory to the ordinary miner as gathering from the alluvium, and further discoveries were made of that nature at the Star river in the Townsville district, at Granite Creek in the Palmer district, and Kangaroo Hills near the coast-town of Ingham. The alluvial tin, however, like the alluvial gold, is not of so permanent a character as is that obtained from the reef or lode; the former disappearing after the lapse of a few years, whilst the latter will probably last while gold remains the standard of value, and until tin is superseded by some more durable metal.

Gold and tin have been the most valuable mineral productions, but copper is largely found in all of the three divisions of the colony; the principal being the Mount Perry copper-mines in the southern, the Peak Downs in the central, and at Herberton in the northern division. These latter are in a highly metalliferous district, which appears to be rich in tin, copper, silver, lead, wolfram, and other metals and minerals, whilst the more precious metal is also found in its immediate neighbourhood. By far the greatest deposits of copper are, however, found in the neighbourhood of Cloncurry in the north-west of the colony, but the distance from the deposits to the sea-coast or to a railway is too great to permit of profitable operations being carried on at present. As evidence of the abundance of copper in that neighbourhood, a slab of pure native copper, which is supposed to weigh about 3 cwts., is in the museum at Brisbane from that locality.

The first appearance of copper as one of the mineral productions of the colony was in the year 1860, when 1 ton valued at £50 was exported, and this export increased rapidly until the year 1868, when over 9,000 tons of ore were exported; during 1872 and 1873 a very much smaller quantity was exported, but, probably owing to more thorough ore-dressing, it was worth double the amount, the highest value exported in any year being £196,000 in 1872. Every year, however, of the existence of the colony has seen the exportation of copper and gold. The value of the former, notwithstanding the stagnation during the last few years owing to the low price obtainable, has now reached £2,000,000.

The only other mineral, the production of which has run parallel with the existence of the colony, is coal, which is not worked so largely as it might be, owing to the large deposits so easily procurable in the neighbouring colony. The beds are not of the same geological age as in Great Britain, but they afford a very useful fuel for steam, gas, or coking purposes, according to locality. The value of the coal worked during the existence of the colony is about £2,000,000, the annual value during the past 8 or 10 years having been from £120,000 to £150,000. It has been found in the Moreton, Darling Downs, and Wide Bay districts of Southern Queensland, and is being worked chiefly in those localities. It is also worked to a less extent in Central Queensland near Clermont, but being far inland, is there confined to local and railway consumption. An extensive deposit covering many thousands of square miles occupies the Dawson country in the same division, and it has also been found in the north, but is not at present being worked there.

The production of silver-ore in Queensland dates from 1874, when 1 ton valued at £60 was exported. Nothing more was done, however, until 1879, when a parcel of 12 tons was despatched; but work appears to have commenced in earnest with 1883, since which time silver to the value of considerably over £500,000 has been obtained. That industry, however, has suffered during recent years owing to the low value of silver, and mine owners prefer to hasten slowly, in the hope that better times are in store for this branch of the miner's calling.

Among the other metals and minerals which have been discovered and partially worked in Queensland are antimony, found at Neardie, in the Wide Bay district of Southern Queensland, and at Northcote and other places in the north. Bismuth has also been found in several localities, and the mine in Southern Queensland which has been devoted to its production is now idle, for want of a market for its produce. Manganese is found plentifully in the neighbourhood of Gladstone in Central Queensland. It is also found in both the northern and southern divisions. Cinnabar and other ores of mercury have been worked at Kilkivan in Southern Queensland, and are known to exist in the north, but are not at present worked. Nickel, cobalt, wolfram, plumbago (graphite) are also found in quantity, but the great desideratum is gold. Investors and practical miners agree in devoting their time, attention, and means to the discovery and extraction of the precious metal.

Precious stones have been obtained in all the principal divisions of the colony. In the south-west opals were first found, and we find that in the year 1882, five packages were exported valued at £1,900. These

stones were procured in the neighbourhood of the Barcoo river (where upwards of 200 men are still at work), and more recently important deposits have been discovered in the central district, which give employment to 300 or 400 men, and necessarily many thousands of pounds' worth are annually obtained, although it is not an easy matter to arrive at an approximate estimate of the real value. Gems, such as sapphires, topazes, rubies, and agates, are also found, but it is difficult to fix a value on them, as there will necessarily be many degrees of quality, and so large a proportion of the ultimate value results from the polishing and setting, that any valuation put on them here is extremely arbitrary, and may or may not be obtained when sold in the London market.

It will be seen, however, that nearly every metalliferous mineral of value is found within the boundaries of Queensland, and it need scarcely be said that earthy minerals and rocks of economic value are also found in abundance. Marbles, limestones, freestones, granites, basalts, and porphyries abound in each of the principal divisions of the colony. The marble of Marble Island, and of other islands in the Percy and Northumberland groups on our north-east coast is well known. The easily worked basalt of Toowoomba, with its facile divisional planes at convenient distances, and the more massive granite of Brisbane, Stanthorpe, and various other portions of the colony yield excellent material for the more important structures in architecture and engineering. Brick-clays, and fire-clays are found in great profusion and variety, both in the sedimentary deposits of the Coal-measures and in the decomposed felspars of the older formations, so that brick and tile-burning, pottery manufacture, and all the branches of the ceramic art, may be carried on when the population warrants the production of such wares in quantity.

Having shown when and at what places the various metals and minerals have been discovered, it will naturally be asked by a society of mining engineers, under what geological and geographical conditions they are found. Are the deposits likely to be persistent, and are the inferior metals and minerals within practicable distances from the coast?

Touching the more important metal, gold, it would be difficult to say under what geological conditions it is not found. Alluvial gold, which has been found to a greater or less extent on all the gold-fields, is generally the precursor of, and guide to, the discovery of auriferous reefs, and is consequently found in the same geological formation as that which encloses the parent reef or matrix from which it has been derived. It may, of course, be washed down the watercourses until it covers other

geological formations ; but this is unusual, as the attrition and action of the atmosphere dissolve, break up, or decompose the enclosing or attached matter, which being only one-sixth to one-eighth of the weight of gold is carried away, and the heavier substance left in the vicinity of its origin. The alluvial gold of the Palmer river, the only important deposit of the kind yet found in Queensland, was found in granitic country. But it is not at all clear that the gold emanated from that source. To quote from a recent report of Mr. R. L. Jack, the government geologist :—

The problem before us was to discover the source of the alluvial gold of the Palmer, about £5,000,000 worth having been taken from the streams and alluvial flats.

Many reefs have been discovered, and a small proportion of the alluvial gold has been fairly attributed to their denudation, but the bulk of the gold has not been derived from the known reefs. As rain is scarce, and the Palæozoic rocks of the district are not such as readily decompose into soils, the naked outcrops of the rocks are well exposed in every valley. It has been remarked again and again by observant diggers that alluvial gold has been rich in gullies whose entire drainage-area did not disclose a single reef.

Over a large portion of the field, the Palæozoic schists, slates, and quartzites, which form the floors and walls of the valleys are capped by sandstones and conglomerates (Desert Sandstone or Upper Cretaceous) which, it is obvious to the most superficial observer, must at one time have formed a continuous table-land. The alluvial gold has in many instances been traced right up to the base of the Desert Sandstone.

This is not the case on the Palmer alone ; it is a remarkable fact that most of the other Queensland localities, where rich alluvial gold has been obtained, are precisely those localities from which the covering of Desert Sandstone has recently been stripped in the course of the everyday process of denudation. The Starcke, the Gilbert, Croydon, the Hodgkinson, the Cape and Cania may be given as instances illustrative of this fact.

Roughly speaking, where the land ceases to be valuable for agricultural or pastoral purposes it begins to contain minerals of commercial importance.

With respect to the alluvial field of Clermont, which is at present the principal source of alluvial gold within the colony, Mr. Jack says :—

There is a considerable diversity in the geological formations in the neighbourhood of Clermont : granite is met with between Douglas and Policeman Creeks, micaceous schists, quartzites and greywackes form the ground-work of the district generally. On Drummond Creek, there is an outcrop of limestone containing *Heliolites* and other Devonian corals. The Coal-measures are met with about 1 mile east of Clermont. Last of all, there are widespread sheets of basaltic lavas, through the denudation of which in the western portions of the district the older rocks have been exposed.

South of Clermont and east of Copperfield, Macdonald's Flat and Deep Creek, both of which are rather insignificant watercourses, are flanked by alluvial deposits of considerable thickness, and evidently of some antiquity, as they have yielded organic remains differing con-

siderably from those of the present day. For 32 years the alluvial deposits of this neighbourhood have been worked by the miners, and at the present day, far from being exhausted, they appear to be capable of considerable extension. About 800 men were working alluvial ground when the writer was there (1891), and he is informed that the number has since been increased.

The geology of our principal gold-field, Charters Towers, has been frequently described, and is, perhaps, the most exclusively granitic of any of the fields. Mr. W. H. Rands, assistant government geologist, who, in company with Mr. Maitland, visited the field in 1892, said that :—

The portion of the field on which I was specially engaged lies to the west of a line, drawn in a north-and-south direction through the race-course. The greater part of this area is composed of the ordinary granite of the field, a rock which in places passes insensibly into a coarse diorite; the granite is hornblendic, and contains very little mica; it is intersected by two classes of dykes, one composed of basic and the other of acidic rocks. The composition of these dykes varies considerably. There is a large area of granite between the eastern and western series of dykes, which, so far as can be gathered from the surface-indications, is practically free from dykes. In this area are situated some of the richest mines, such as the Brilliant, Victory, Victoria, etc. On the north-western portion of the field there is a large wedge-shaped mass of slates which dip steeply in a north-easterly direction.

Mr. Maitland gives similar testimony, viz. :—

The portion of the field which has been allotted to me . . . turned out to be much more difficult than had been anticipated, owing to the complexity of the geological structure. By far the larger portion of the ground is composed of granite, and a very coarse-grained rock, containing hornblende, mica, and a triclinic felspar—a quartz-diorite. The granite penetrates those sedimentary beds, which form the lesser portion of the ground. The sedimentary rocks consist for the most part of indurated siliceous rocks (approaching very closely to quartzites), sometimes very micaceous.

It is needless to give more detail, as these extracts show the leading geological features of the field.

Touching the formation at Gympie, Mr. Rands reports thus :—

The whole area of the Gympie gold-field, with the exception of the small areas above mentioned (alluvium and a coarse-grained siliceous sandstone or freestone known here as Desert Sandstone), consists of rocks, which may be referred to the series called the Gympie Beds. It is in these beds that all the reefs occur and they will be described in detail in this report. The Gympie Beds have generally been referred to the Devonian system; but Mr. Robert Etheridge, jun., to whom collections of fossils, made by Mr. Jack and myself, were sent, considered them to be homotaxial with the Carbonifero-Permian rocks of Europe. The most important part of the field presents a series of alterations of different kinds of sedimentary strata with some intrusive igneous rocks, and also some of volcanic origin. Taking the average dip at 22 degrees, there would be somewhat over 2,000 feet in thickness of such strata.

The rocks of which these beds are composed consist chiefly of greywackes, altered sandstones, grey and black carbonaceous shales, grits, conglomerates, breccias, and limestone. Interbedded with these are amygdaloidal volcanic rocks and volcanic ash. There are also sheets of an intrusive greenstone, which has undergone great alteration.

Mr. Rands then gives a section of the strata abovementioned, commencing with the Blue Limestone, which is fossiliferous, and at 600 feet reaches the Phoenix Slates, which are 200 feet in thickness, and at 130 feet further the so-called first bed of slate is reached, the Phoenix Slates being always spoken of separately from the first, second, and third beds of other parts of the field. The first bed is 15 feet thick, at about 80 feet further the second bed is reached, given as 13 feet in thickness, and after 612 feet more the third bed is reached. It is a remarkable circumstance that where the reef comes into contact with these slates it bears heavily, but is generally barren elsewhere.

It is unnecessary to quote further from Mr. Rands' very complete report, nor is it advisable further to pursue the question of the geological formation of the gold-fields—except as to Mount Morgan, which could not well be omitted. A very few extracts from Mr. Jack's report, however, will suffice. He states that :—

Mount Morgan itself contains gold in a very unusual—I believe a quite unprecedented—formation. Aneroid measurements give the altitude of the mountain as 1,225 feet above sea-level. The central portion of the upper cutting is a large mass of brown hæmatitic ironstone generally in great blocks (up to some tons in weight), with a stalactitic structure, as if the iron oxide had gradually filled up cavities left in the original deposit. The ironstone contains gold of extraordinary fineness, which, however, after a little practice, can be detected in almost every fresh fracture. The ironstone is more or less mixed with fine siliceous granules, passing into pure kaolin, with some silicates of magnesia, including a fine variety of French chalk.

The lower or Magazine face presents a sort of fanlike arrangement of its various materials. In the centre is a band (almost vertical) of brown hæmatite in large bombs, with a mammillated, botryoidal, or sometimes reniform appearance. To the right (east) is a nearly vertical deposit of aluminous iron-ochre, followed by a mass (still nearly vertical) of red hæmatite in large cellular bombs. To the east is a broad mass of loose ironstained siliceous and aluminous material which begins to lean eastward like the outer feathers of a fan. A great mass of loose earthy hæmatite, another of brown hæmatite in large (ton) blocks appear in succession as the cutting is followed to the east. . . . Down the hillsides to the north-west and south a similar deposit is everywhere met, with a frothy or spongy matrix, sometimes aluminous and sometimes siliceous, generally ironstained, and occasionally associated with large masses of red and brown hæmatite. After a careful study of the whole formation I have come to the conclusion that nothing but a thermal spring in the open air could have deposited the material under consideration. The frothy siliceous sinter agrees in every respect with the deposits of New Zealand and Iceland geysers, and of the still more wonderful hot springs of the Yellowstone National Park so graphically and scientifically described by Dr. A. C. Peale, Washington, 1883.

The discovery of gold at Mount Morgan is one of the most important events in the history of the mining industry. It is not merely that the quantity is large, and that certain shareholders will be enriched, but the possibility that the discovery may lead to others of equal importance in a direction where gold has never hitherto been looked for lends it a wider significance. Given a hot spring rising from depths in which auriferous reefs lie hidden, we may look for a repetition of the phenomena of Mount Morgan.

Touching the geology of the country in which the useful (as distinct from the precious) metals are found, it is unnecessary to say much; those members who are acquainted with the tin-bearing geological formation of Devon and Cornwall will be able to form a good idea of the position in which that metal is found, as it seems to be more closely identified with the granitic than is any of the other metals with any particular class of rocks. The alluvial tin-stone, which constitutes a large proportion of the yield, may of course be found in the neighbourhood of other rocks, but is generally found in the detritus of the granitic formation. Of course the word may be taken to include the whole family of igneous rocks, granite, syenite, porphyries, etc., which are intersected by dykes of elvan or felsite, with varying degrees of metamorphism, in which the tin-ore is found.

Mr. Jack, writing in 1888, said that :—

A continuous track of nearly 200 miles in length of stanniferous country has thus been added to the wealth of the colony within the last three years.

One fact unnoticed and unsuspected when I wrote my first report comes out clearly and unmistakably from a detailed examination of the field, now that something more than the mere surface is accessible to observation. This fact is the intimate connexion of the tin-deposits with metamorphosed igneous dykes; such dykes emanating from a deep-seated reservoir of molten matter, forced their way under pressure into fissures in the solid porphyry rock and consolidated as basic igneous rocks. The basic rocks of the dykes seem to have undergone a gradual process of metamorphism. The dykes now consist mainly of quartzose chlorite and occasionally of quartzose serpentine. It may be inferred that they were originally consolidated as quartz-diorites or as rocks more or less of the basaltic type. The tin occurs in floors, veins, or pipes among the joint-planes of the dykes.

As the dykes have originated in a deep-seated mass of molten matter, they may be expected to carry the tin-ore to greater depths than are ever likely to be reached by mining. The metamorphosed dykes are traversed by a series of dykes of quartz-porphyry strictly analagous to the elvans of Cornwall.

A short distance from the tin-lodes, the galena, copper, and zinc ores commence, where the slates predominate, with occasional greywackes and shales. It is unnecessary, however, to continue the description of the geological formation in which the minerals are found. A few of the results of work may be more to the point.

The total production of metals and minerals is now bordering on a value of £50,000,000, of which sum £10,000,000 is represented by the inferior metals and minerals, and nearly £40,000,000 by gold.

It has sometimes been said that every ounce of gold costs its value to procure it. If this be true anywhere, it is certainly not so in Queensland.

Let us look at the number of men employed in reef-mining during the past 10 years and the quantity of gold obtained. The figures are taken from the *Official Report of the Mines Department*. The writer takes those employed in reef-mining, because alluvial-mining gives no certain data for statistical purposes. For instance, it has been shown that the Palmer river yielded £5,000,000 of alluvial gold. This would incur comparatively little expenditure of either labour or capital. On the other hand, men who do not care to settle down to regular work at the mines take to alluvial-mining, and frequently have to be content with small earnings, but retain their independence, as for a payment of 10s. per annum they may work on any unoccupied Crown lands. And further, even a very rich alluvial patch is in all probability soon exhausted. It is on reef-mining that the stability of the industry depends, the proportion of alluvial gold obtained during the 10 years 1886-1895 having been less than $3\frac{1}{2}$ per cent. of the whole.

The average number of men employed in reef-mining during those years has been 7,612·8, and the average quantity of gold obtained 553,278 ounces, which at the very reasonable estimate of £3 10s. per ounce gives £1,936,473, or £254 7s. per man employed. It will be understood that the value of gold as found in the earth is variable according to its purity, that in Queensland being generally worth about £3 10s., although the alluvial and that from Mount Morgan go much higher. The latter ranges up to £4 4s. per ounce.

The wages paid vary in the different districts : at Gympie—probably on account of its being furthest south, nearest the sea-coast, nearest the capital, and the oldest field, £2 10s. per week is the figure ; at Rockhampton the same ; at Charters Towers £3 ; and at Croydon £3 10s. In most of the gold-fields the spare cash of the miners is invested in shares in the mines, and thus to a considerable extent the capital (real or nominal) is that of the miners themselves. The nominal capital of the Queensland gold-mines approaches £10,000,000. The real capital, except what is represented by machinery and shafts, etc., paid for by the earnings during the progress of the work is probably not nearly one-tenth of that amount. It is interesting to note the relative proportion of paid-up

to nominal capital, and to actual capital subscribed. Thus, the No. 1 North Phoenix gold-mine at Gympie was commenced with a small nominal capital, of which £2,670 was called up before the mine became self-supporting and began to pay dividends ; but it has now paid £418,750 in dividends, besides erecting £30,000 worth of machinery on the ground. Its nominal capital is now £40,000 in 40,000 shares of £1 fully paid up. That is, the mine was valued at that amount, and a re-arrangement was made under which the increased number of shares was distributed *pro rata* without further payment. The No. 1 North Glanmire is a company of 24,000 shares of 5s. each, of which 3s. 9d. has been called up ; but it has now paid £297,200 in dividends. The Phoenix P.C. gold-mine was originally in 12,000 shares, and very soon began to pay dividends. Its nominal capital has been increased—first to 36,000 shares, then to 50,000, and latterly to 100,000 at £1 each ; it has paid £232,866 13s. 4d. in dividends, and a company which took a portion of the mine on tribute for a while paid £19,675 in dividends, making £252,541 13s. 4d. from that mine. Now, we will take an example of a different kind. The Phoenix Golden Pile gold-mine of 48,000 shares was formed in 1879, and it was kept going—mostly by calls—for 14 years, until 11s. 7d. per share had been called up, or £27,800, and then gold was struck. The first dividend was declared on October 9th, 1893, and now £1 8s. 1d. per share or £67,400 has been paid in dividends, and it continues in a very healthy condition. The Great Eastern, Ellen Harkins, Wilmot Extended, New Zealand, Monkland, and Glanmire mines have at one time or other of their existence paid marvellous dividends, and now the Columbia and Smithfield, North Smithfield, No. 4 North Phoenix, and others are taking their place.

A little further north, in the Central District of Queensland, the Mount Morgan, with its £1,000,000 of nominal capital, has now paid £4,250,000 in dividends. Further north again, is Charters Towers, where the nominal mining capital amounts to more than that of all the rest of the mines in the colony put together, viz., about £5,000,000. The Brilliant gold-mine with 260,000 shares issued as paid up to £2 per share, constitutes the whole nominal capital. The mine had paid handsomely for some years, and it has paid during the last six years £279,666 in dividends. And in the following year “the results also from the Brilliant mine have exceeded the most sanguine expectations of the owners. The mine has paid 100 per cent. on the *nominal* capital during the past year, and promises to pay even a larger percentage for some time to come.”

The first year for which any definite information was given touching the dividends, was 1890, and it may be well to tabulate the results during that and the following years.

Name of Mine.	1890.	1891.	1892.	1893.	1894.	1895.
	£	£	£	£	£	£
Brilliant	50,000	75,000	37,500	18,750	43,166	55,250
Day Dawn P.C.	53,875	37,500	12,250	97,500	101,250	45,000
Mills United	—	26,250	22,500			
{ Day Dawn Block and	—	24,920	—	—	—	—
{ Wyndham from 1892	—	—	49,840	12,500	—	12,500
Victoria	16,200	14,400	41,400	32,400	21,600	32,400
Sunburst	2,400	20,400	1,200	—	—	—
Kelly's Queen Block ...	—	—	6,000	15,800	15,800	2,400
Victory	7,500	2,500	97,500	80,000	5,000	—
Golden Gate	6,600	18,600	24,300	—	—	—
New Queen	4,000	12,000	4,000	7,972	7,972	3,973
No. 7 N.E. Queen ...	1,500	10,200	24,000	—	—	—
Brilliant and St. George	—	—	2,400	10,800	33,000	57,600
Cravens Caledonia ...	—	—	—	7,500	2,500	—
Brilliant Block	—	—	—	2,500	36,250	27,500
Brilliant Central	—	—	—	1,666	11,250	2,500
Other dividends	10,737	13,250	18,802	13,510	11,286	5,677
Totals	152,812	255,020	341,692	300,898	289,074	244,800

More than £1,500,000 of dividends from one gold-field in six years, and these are not all, as the 1891 report states that in addition to those given many other mines have yielded handsome dividends.*

In dealing with the principal minerals in Britain, coal, ironstone, slate, and the like, members are fully alive to the advantages of water-carriage, or, in its absence, a well equipped railway. But for the greater part with us these facilities are conspicuous by their absence. Nothing strikes a visitor to your country from ours so much as the contrast of distances, heightened, as it is, by means of rapid locomotion in Great Britain: you appear to be "cribb'd, cabin'd, and confined" in a small space, whilst Queensland is a country of magnificent distances. Touching the discovery of gold at the Palmer river, 25 years ago, it has been said that:—

The difficulties of travel, the absence of the necessities of life, the impassability or utter absence of roads, the inhospitable nature of the climate, the miasmata of the swamps, the certain danger from the natives, were all as though they had not been; and such have not yet been experienced that would deter the adventurous and intrepid digger from pursuing his quest of gold and penetrating to its probable location on the first hint of the proof of that probability.

And so it may now be said in respect of the inferior metals. There is scarcely any part of Queensland to which a rush would not now set in,

* The dividends during 1896 were £254,616.

if a discovery of alluvial tin were reported, or even a likely find of silver, for the means of travel and the difficulties met with 25 years ago have been greatly ameliorated. Railways, roads, and telegraphs have been multiplied, stations, and even townships, have been established where supplies can be obtained. Extensive gold-fields and mining districts have been located, and all the accessories of incipient civilization have been scattered broadcast, although thinly, over the territory.

Is it probable that further discoveries will be made? Is there evidence to justify further development of the mining industry? Having had the good fortune to join the Right Reverend the Bishop of Brisbane in a railway-carriage recently on his returning from a pastoral visitation, the writer was informed by his lordship that during his visit he had heard of the very recent discovery of a fine lagoon on some table-land in the Burnett district, in Southern Queensland, and within 100 miles of the coast. Now, can anything show more clearly than this incident how little we know of the geology of the country when we do not know the geography of the most thickly peopled, the southern district of the colony, for the locality referred to has probably been held as a cattle or sheep-run for nearly 50 years?

The area of the country now proclaimed as gold-fields is 17,607,200 acres or 27,515 square miles, and as mineral areas, or more correctly mining districts, 22,879,200 acres, equal to (nearly) 35,750 square miles. It is less than one-tenth the area of the colony when taken together, but more than the whole area of England and Wales together, or of Ireland and Scotland combined, so that there is abundant room for exploration and exploitation.

In a recent bulletin from the Geological Office dealing with the Hodgkinson gold-field, which embraces 2,072 square miles, Mr. Jack stated that "the Hodgkinson is, in my opinion, most undeservedly a neglected gold-field," and he gives an abundance of tabulated results to prove the correctness of that opinion. He continues :—

The crushings from the Hodgkinson have averaged as well as those of any other gold-field in the colony, and yet the mines, one after another, were abandoned, in spite of a yield which anywhere else would have stimulated the holders to a feverish activity. . . . The field was taken up at first by miners, who contributed nothing but muscle. Now, muscle is an admirable and enviable possession, but it is not capital. The miner endowed with muscle alone has all the time to live on the proceeds of the mine. It is only with the surplus of earnings over living and working expenses that he can do any "dead work." In other words, the development of the mine has to be carried on out of revenue instead of out of capital. That scores of Hodgkinson miners did so for years, in spite of every drawback, is an achievement to be proud of. As a matter of fact the first check,

THE HISTORY OF THE UNITED STATES

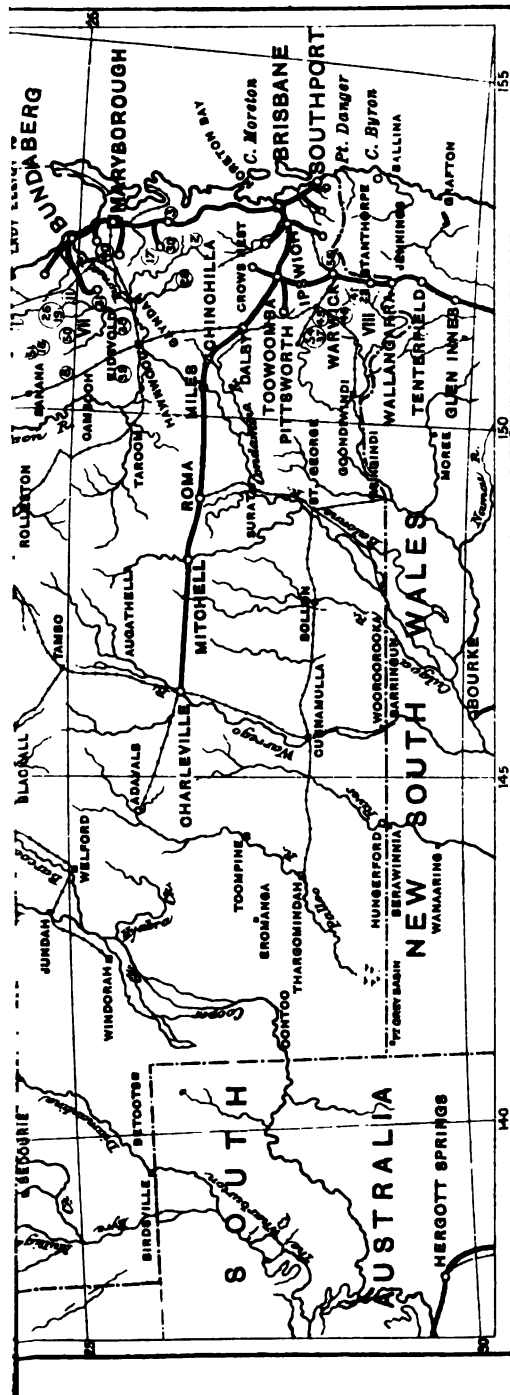
The history of the United States is a story of a people who have grown from a small colony of Puritans to a great nation of free men and women. The story is one of struggle and triumph, of hardship and hope.

The first chapter of our history is the story of the Pilgrims. They came to America in 1620, seeking a new life and a new freedom. They found a land of wild beauty and a people of noble spirit. They were joined by the Indians, who taught them the ways of the forest and the ways of peace. Together they built a new nation, a nation of free men and women.

The second chapter of our history is the story of the Revolution. It was a time of great struggle and great triumph. The people of America fought for their freedom and won. They established a new government, a government of the people, by the people, and for the people.

The third chapter of our history is the story of the West. It was a time of great discovery and great adventure. The pioneers went westward, seeking a new life and a new freedom. They found a land of wild beauty and a people of noble spirit. They were joined by the Indians, who taught them the ways of the forest and the ways of peace.

The fourth chapter of our history is the story of the Civil War. It was a time of great struggle and great triumph. The people of America fought for their freedom and won. They established a new government, a government of the people, by the people, and for the people.



the first sign of diminution of the yield, such as is common in all mines, was the signal for the desertion of every "show" on the Hodgkinson. The profits already made had been otherwise disposed of, and there were no funds available for prospecting work. Many mines even seem to have been thrown up while in the full tide of prosperity, or what should have been prosperity under favourable conditions.

But there was another reason, tin had been discovered at Herberton, and was being discovered anywhere from 50 to 100 miles distant, and that had a great deal to do with the desertion of the Hodgkinson, when with industry and economy that field ought to have prospered. The writer visited it in 1882, when it was being deserted, and was fully of the opinion expressed by Mr. Jack. That is, however, a very good indication of the manner in which a gold-field becomes prosperous or otherwise. Men of muscle develop mines which pay from the beginning. They, after a while, form companies, get machinery, develop the mine, possibly have a considerable nominal capital, but everything is paid from the profits of the mine, or in hard cases the share-calls are paid from the wages, and when rich gold is struck, or from economical methods of working a smaller yield will pay, the original shareholders are recipients of good dividends, or the mine is floated as a company.

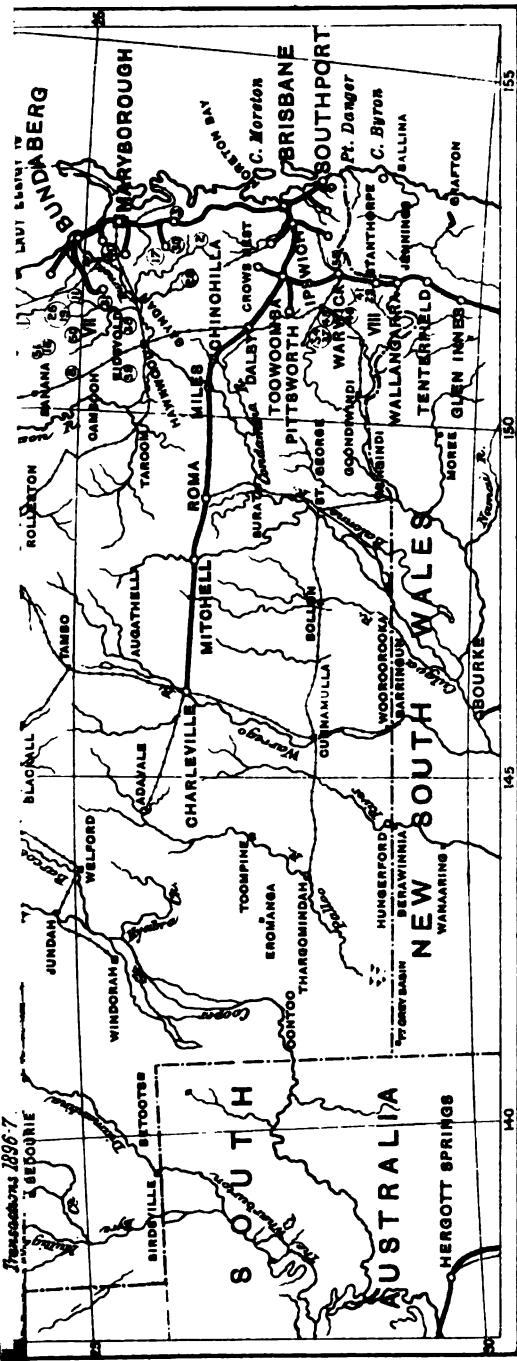
In too many instances, whatever may be said of industry, economy is certainly not practised. Good results mean riotous living, and when a report of new discoveries comes along, away goes the nomadic digger and a claim is left which, with industry and economy, might have been the foundation of a fortune, but which is not so easily taken up again, even if the former restless possessor cares to return to the mine which he has abandoned.

After enumerating the difficulties of 1880-83, when the field was abandoned, Mr. Jack stated :—

At the present day the drawbacks referred to hardly exist. A railway has been brought to within 35 miles of the centre of the field, doing away with the difficulty of the "coast range." Every form of mining and gold-saving machinery is cheaper and more efficient, and the expense of putting it on the ground is a mere fraction of what it cost in the old times. Food-stuffs only cost a tithe of the famine prices of yore. Every item of expense—carting, crushing, timber, and labour—is lessened. The figures speak for themselves, and if they were not authentic official records, they would strike one as incredible.

The Etheridge gold-field, with its adjunct, the Woolgar, contains 10,000 square miles of country, and although on several occasions important discoveries have been made and rich patches worked for a time, the field does not make much head-way, being isolated from either water or railway communication with the rest of the world. It is known to be a network of reefs, however, which will certainly add to the wealth of the

*The Australasian Institute of Mining Engineers
Transactions 1896-7*



*North of England Institute of Mining & Mechanical Engineers.
Transactions 1896-7*

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colony at no distant date. It has already produced more than 500,000 ounces of gold, and, like the Hodgkinson district, requires the investment of capital. "An area of enormous extent, saturated with gold from the surface downwards," is the statement of the warden in his last annual report.

The writer will not further exhaust the patience of the members with descriptive or statistical matter. He has said nothing about the appliances used, or the methods of working adopted, and the members may, he thinks, accept the statement that on the older gold-fields, such as Gympie and Charters Towers, and at Mount Morgan, the best appliances are provided, skilful management secured, and an able and industrious class of men employed. It can hardly be supposed that these conditions prevail at the outside places where the mode and circumstances of life are essentially different, and are scarcely likely to attract steady-going men who have married and settled down to comfort and happiness.

APPENDIX.

REFERENCES TO THE MAP OF THE COLONY OF QUEENSLAND (PLATE XIX.)

Area of Queensland, 427,838,080 acres; population, 445,155. Area of proclaimed gold-fields, 17,607,200 acres; area of proclaimed mining districts, 22,879,200 acres. Total output of gold to 1896, 10,558,605 ounces at £3 10s. per ounce, £36,955,117.

GOLD-FIELDS.

1. *Callipoe.	20. Nebo.	40. Paradise.
2. *Yabba.	21. *Etheridge.	41. Palgrave.
3. *Gympie.	22. *Hodgkinson.	42. Euengella.
4. Mount Morgan (Crocodile Creek).	23. *Langmorn.	43. Strathalbyn.
5. *Ridgeland.	24. Mulgrave.	44. Stanwell.
6. *Rosewood.	25. Mount Wyatt.	45. *Thane's Creek.
7. *Morinish.	26. *Milton.	46. *Canal Creek.
8. *Cania and Kroombit.	27. Normanby.	47. *Cawarral.
9. *Woolgar.	28. Nanango.	48. Grasstree.
10. *Clermont.	29. *Pikedale.	49. Coen River.
11. *Boolboonda.	30. Glastonbury.	50. Monal Creek.
12. *Charters Towers.	31. Reid's Creek.	51. Maxwellton.
13. *Cloncurry.	32. Russell River.	52. Ulam.
14. Croydon.	33. Yatton.	53. Horn Island.
15. *Cape River.	34. Canoona.	54. Leyburn.
16. *Ravenswood.	35. *Mount Spencer.	55. Springsrush.
17. *Kilkivan.	36. *Palmer.	56. Lucky Valley.
18. Barmundoo.	37. *Talgai.	57. Mareeba.
19. Bomp.	38. Eidsvold.	58. Bower Bird.
	39. St. John's Creek.	

* Mining districts.

The CHAIRMAN moved a vote of thanks to Mr. Fryar for his valuable paper, which was cordially agreed to.

The SECRETARY read the following paper by Mr. W. T. Hallimond on "Notes on the Coal-seams of the Transvaal, and Description of a Modern Pit-head Plant":—

NOTES ON THE COAL-SEAMS OF THE TRANSVAAL, AND
• DESCRIPTION OF A MODERN PIT-HEAD PLANT.

By W. T. HALLIMOND.

It is not so much the writer's object to set forth any theory of the formation of the coal as to describe the exact conditions under which the seams are found, as well as the machinery best adapted for their treatment in the Transvaal.

After careful thought, the writer decided that a short paper would be more beneficial (especially to members connected with coal-mining in the Transvaal) at the present time than to raise discussion on the geological nature of the coal-fields. New pits are being sunk in the different districts of the southern Transvaal, all of which are throwing more light on the much-debated question of how the coal-seams were formed, and at a later date the writer will be pleased to give the members the benefit of such information as he has collected during his nine years' experience of the coal-fields of the Transvaal.

The coal of the southern Transvaal is undoubtedly all of the same age, although the beds are not continuous, but are found in basins, and are very variable, both in quality and thickness as well as in area. The writer has found this variation prevailing as much in the bituminous coals of the Middelburg district as in the steam coal-basins of the Boksburg, Brakpan, and Springs districts.

The writer is of opinion that the coal-deposits are of subaqueous origin and were formed after the tilting of the Banket formation of the Rand. At two collieries in the Boksburg coal-basin, the Banket bed itself has been struck not far below the coal, and at the Phoenix colliery (of which he had charge) a heading was driven in coal against the tilted gold-formation. A reference to the geological plan and section (Figs. 1 and 2, Plate XX.) will serve to illustrate the above statement.

There are several factors in connexion, not only with the coal of the Transvaal, but with what may be termed the South African coal-field, which, to the writer's mind, tend to prove that the coal had not been formed *in situ*; but that the vegetable matter now found in the form of

coal was borne by water and deposited in the basins in which it now occurs in its mineralized state. One of the strongest evidences of this theory is the varying quality and thickness of individual seams of coal, together with the coal-seam itself containing what might be called pockets of what had originally been black mud. The writer has had considerable experience in the Middelburg coal-district in the Transvaal, where undoubtedly the best quality of coal in the country is found, and he annexes a section of the seam (Fig. 3, Plate XX.), showing its varying thickness and quality, accompanied by pockets of black shaly rock. The general section of the seam is from 4 to 6 feet of bright bituminous coking coal at the top, with 7 or 8 feet of dull coal lying underneath; but the writer has found the bright coal to turn dull, and the total section to diminish to 5 feet and then increase again to 15 feet, the undulation in every instance being on the floor of the seam only.

At the Rand collieries (where the writer is at present in charge), at Brakpan, Cassel, Great Eastern, and Clydesdale collieries, all in the same district, the shafts, after going through the coal, have penetrated a conglomerate of sandstone with quartzite-pebbles.

The absence of clay immediately underlying the coal is, in the writer's opinion, as great a proof against the *in situ* theory of the formation of the coal, as is the scarcity of fossils. He has never yet seen, in 15½ years of South African experience, a bed of fireclay immediately underlying a seam of coal, nor has he ever found a fossil on the floor of the seam. Fossils have always been found on the roof or in the coal-seam itself. He possesses a specimen (recently found at the Rand collieries) of *Favularia tessellata*. This fossil was found in the coal, and its substance is also that of coal.

The late Prof. Green's remarks on the formation of South African coals are very distinctly in favour of a subaqueous theory, and the writer entirely agrees with him. Prof. Green said :—

All, or nearly all, known coals have been formed in one or other of the following ways :

In the case of some coals, the plants out of which it has been formed grew on land over ground where the coal is now found. Coals formed in this way may be called terrestrial coals; as a rule, they contain a small percentage of ash, and they frequently maintain a fair regularity in thickness and uniformity in character over large areas.

In other cases, plants have been carried by running water into ponds or lakes, have sunk to the bottom, and in this way have given rise to a layer of vegetable matter, which has subsequently been converted into coal. Coals formed in this way may be called subaqueous coals; they will be liable to contain a large percentage of ash, for the rivers will bring down mud and sand as well as plants, and

the deposit formed on the bed of the lake will be a mixture of earthy and vegetable matters. There will also be a risk that this class of coals will be more variable in thickness and more limited in extent than terrestrial coals, for a substance as light as wood, leaves, or twigs, is not likely to settle down very regularly, and the area over which the coal extends cannot be greater, and may be less than that of the lake in which it was formed.

The two classes of coal can almost be distinguished by noticing the kind of rock that lies beneath them. In the case of a terrestrial coal, the stratum immediately below it is thickly crowded with the roots of the plants which furnished the material for the coal. It is really nothing else but the soil in which these plants grew. To it the names "underclay" and "seatstone" have been given. There will obviously be no such seatstone under a subaqueous coal. Now, in no single case have I been able to detect anything approaching a seatstone in character under the South African coals, and on this ground alone I should be strongly inclined to suspect that they are subaqueous.

The writer's experience of all South African coals is that they possess the drawback of containing a large percentage of ash, and as this paper is not altogether a geological one, but more an attempt to briefly explain the class of coal that a mining engineer in South Africa has to consider and provide for in the ordering of machinery for its treatment on arrival at the surface, he will now state that the most important questions to be considered in ordering a plant of modern type are :—

(1) The quality of the coal to be treated, and classes to be divided. The coal is all of a very hard nature. Dynamite being used as an explosive (costing nearly 2s. per pound), there is a large percentage of small coal made for which as yet there is no demand. This small coal question is one demanding the grave consideration of all engineers interested in coal in the Transvaal. Blasting-powder would naturally save much waste in small coal, but unfortunately the only powder obtainable is that manufactured in the Transvaal, which in the writer's experience has proved a perfect failure.

Two classes of coal only are made for the market, viz., round and nuts; the duff or dust is tipped with the sorted shale and inferior coal on to the *débris*-heap. In ordering mechanical screens or jiggers, the engineer has therefore to study how he can best obtain the maximum quantity of round coal and the minimum of duff coal, at the same time producing nuts free from dust and dirt, for which there is always a ready sale. The average price at present at the pit is 9s. for round and 6s. for nut-coal.

Although the plant to be described was not originally ordered in its present form as far as the cleaning and classification of the coal is concerned, these are details which can always be arranged to suit the local conditions of any colliery.

The writer is at present using on the whole length of the jigging-screen bevelled bars with $\frac{7}{8}$ inch spaces. The screen is 20 feet long. All the coal passing over this screen goes on to the round-coal belt, is picked and distributed into bags. The coal passing through the jigging-screen simply runs by gravitation over screening-gauze of $\frac{3}{8}$ inch mesh into a hopper, where the nuts are collected and drawn off through sliding-doors into bags. The dust falls through the $\frac{3}{8}$ inch mesh into another hopper, and is taken away from thence in the small trucks to the *débris*-heap. It has been advanced that rotary-sieves are better screeners than fixed screens. This, in the writer's opinion, is wrong in theory, and in practice he has found that more nuts were made over a fixed



Fig. 7.—General View of the Rand Colliery, from the South-west.

screen than through a revolving-screen, not to speak of the power required to drive the latter. A rotary-screen contains to a certain extent the elements of a coal-disintegrator, and a certain amount of nuts are (by being thrown about in the rotating-machine) converted into dust, and so passed off to waste through the meshes of the sieve, which, over a fixed screen, where the coal moves by gravitation only, would pass into the bags for sale.

(2.) The saving of labour in banking-out and sorting. As white labour is too expensive in South Africa for banking-out work, the arrangement, as hereafter described, is a great saving of labour on the

old system where so many Kafirs were employed. On the present output, the saving by the modern appliances for banking-out and tipping amounts to 3½d. per ton.

Sorting- or picking-belts cannot be too long. As the writer has already endeavoured to show, the coals of the Transvaal are so very erratic in their quality that the engineer must be prepared for a large amount of picking, and the belts ought therefore not to be shorter than 50 feet and at least 5 feet wide, so that the boys can pick from both sides. Now that the gold industry has expanded to its present large dimensions, competent managers are being employed, and they naturally



Fig. 8.—General View of the Rand Colliery, from the South.

insist on having the best fuel, and it is only by having the latest appliances for cleaning, screening, and picking the coal, that ready sale can be made.

(3.) The most economical mode of bagging the coal. All coal in the Transvaal, as yet, must be bagged at the mine to suit the whims of the Netherlands Railway Company, who have a monopoly of the railways in the country. The old system at collieries working is to deliver the coal from the screens or belts on to a huge tray lying almost flat, and from thence the coal is shovelled by hand into bags. The saving by the use of distributing-shoots, as adopted at the Rand collieries, is about 8½d. per ton on the present output. The combined saving amounts to 1s. per ton over the old systems of banking-out and bagging.

DESCRIPTION OF PLANT AS ERECTED AT THE RAND COLLIERIES.
(Plate XXI.)

The pulley-frames are 55 feet 4 inches high to the centre of the pulley wheels, and these, together with backstays, etc., are built of steel trellis-work, well stayed with diagonals and cross-bracing. The feet are set in cast-iron shoes mounted on large cap-stones set on concrete beds and firmly bolted together. The backstays, 66 feet long, sit in cast-iron shoes on cap-stones at the end of abutments forming part of the engine-beds, 18 feet high. Hand-rails and steps are fitted to one backstay,

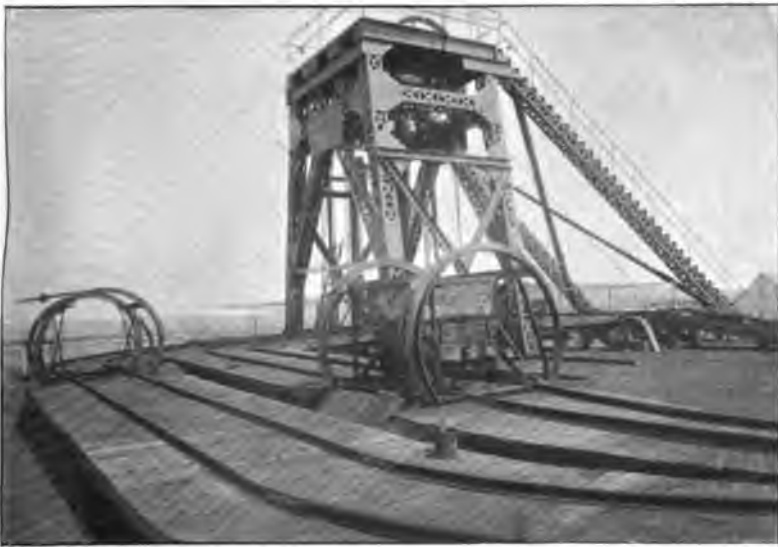


Fig. 9.—Banking-out Platform, showing Tippers, Creepers, etc.

leading from the engine-house. The pulley-wheels are 7 feet in diameter. The frames are riveted throughout, and are exceptionally rigid (Figs. 7 and 8).

The heapstead and sorting-platforms carrying the screens, picking-belts, tipplers, creeper, and shafting are built of timber, having 86 uprights, each anchored to a block of masonry, cap-stone, and shoe. The back and front stays and the trussing under each screen reduce the vibration to a minimum.

The top deck of the heapstead, from the cage-landing, is on a downward grade ($2\frac{1}{2}$ feet in all) upon which the tramways are laid. Each full truck, as it enters the tippler, pushes out the empty one, and this runs by gravitation to the end of the creeper, where the axle of the tub

is caught by the horns of the creeper-chain, and taken up an incline to the flat-sheets ready for the cage again.

The tippers are of the revolving type, tipping sideways on to the screens. A counter-shaft with keyed rollers, and a pair of loose rollers, attached by links to a second shaft, are driven continuously from the screen main-shafting. The second shaft is controlled by a working lever, which, when lifted, brings the loose rollers into gear with the third set, starting the tippler. When the tippler is at rest, a projection on the working lever lies in a slot on the tippler-flange. After the lever is lifted and the rollers geared, the projection on the lever rides in a groove around the flange till a revolution is completed, then the projection again falls into the slot and the gear is thrown out (Fig. 9).



Fig. 10.—Picking-belts Platform, showing Jigging-screens, etc.

The jigging-screens, which have already been partly described, are driven by belting from the main-shafting, and an eccentric with connecting rod and levers gives the jigging motion to the screens (Fig. 10).

The picking-belts are 25 feet and 32 feet long by $5\frac{1}{2}$ feet wide, and are geared to travel at the rate of 60 feet per minute. At the end of the belts a vibrating plate throws the coal over the apron, which is cambered, and dividers direct the coal towards the bagging-doors. At the top of the distributing-shoot or apron a dead-screen takes off the small coal made in breaking up big lumps on the belts. (The lumps have to be

broken for bagging.) If it be required in future to load coal without bagging, the screen in the shoot lifts up and the coal can be loaded direct into trucks (Fig. 11).

The jiggingscreens, picking-belts, tipplers, and creeper are all driven by an engine with two horizontal cylinders, 10 inches in diameter by 18 inches stroke, fitted with variable expansion-gear and automatic governor. If necessary any part of the machinery can be thrown out of gear without stopping the driving-engine.

The winding-engine is of the horizontal direct-acting type, having two cylinders each 20 inches in diameter by $3\frac{1}{2}$ feet stroke with drums $6\frac{1}{2}$ feet in diameter. The engine is firmly fixed on solidly-built stone



Fig. 11.—Coal-bagging Platform, showing Distributing-shoots, etc.

foundations, at a height of 13 feet from the ground, thus bringing the cylinders above the level of the top of the boilers. The foundations themselves are built up solid at the end next the head-gear, forming a strong buttress for the backstays of the pulley-frames.

Steam is supplied by two Lancashire boilers of the ordinary type, 28 feet long by 7 feet in diameter, carrying a steam pressure of 90 pounds to the square inch. The smoke-funnel, 72 feet high by 7 feet in diameter, is built of wrought iron, and riveted in position. A conical wrought-iron base or outer shell, $9\frac{1}{2}$ feet in diameter at its base, joins the smoke-funnel proper at a height of 16 feet above the bed-plate. The

whole is securely bolted to the bed-plate, which is about 5 tons in weight and mounted on a bed of masonry 14 feet square by 8 feet high. The holding-down bolts, 3 inches in diameter, pass downwards through the masonry into $2\frac{1}{2}$ feet of concrete below.

The coal tubs are of the Marsden type, built of wood, with angle-iron corner-posts. They are of 20 cubic feet capacity, and fitted with 11 inches wheels. The gauge of the road is $2\frac{1}{4}$ feet. These trucks are wearing well, and for their size are very easily handled by the Kaffirs.

The cages are built of steel, with room for two tubs on the single deck. Walker detaching-hooks are fixed on the winding-ropes. One of these hooks has been accidentally tried since the colliery started, and the writer is glad to say that it worked without a hitch, and the pit was stopped for about $\frac{1}{2}$ hour only.

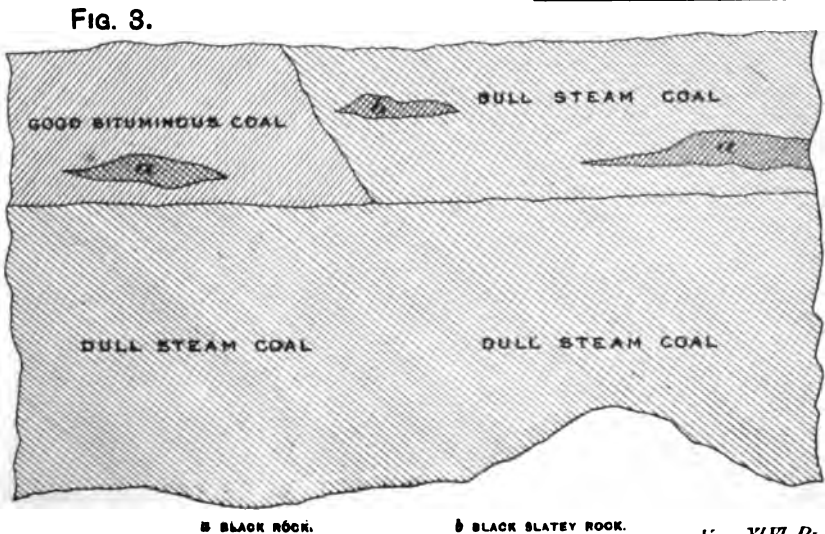
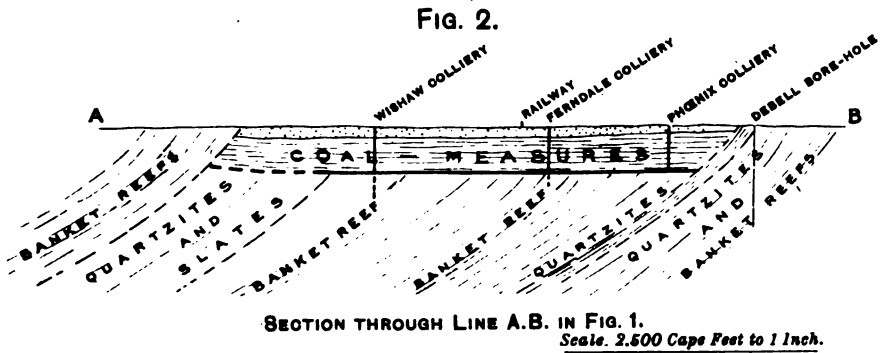
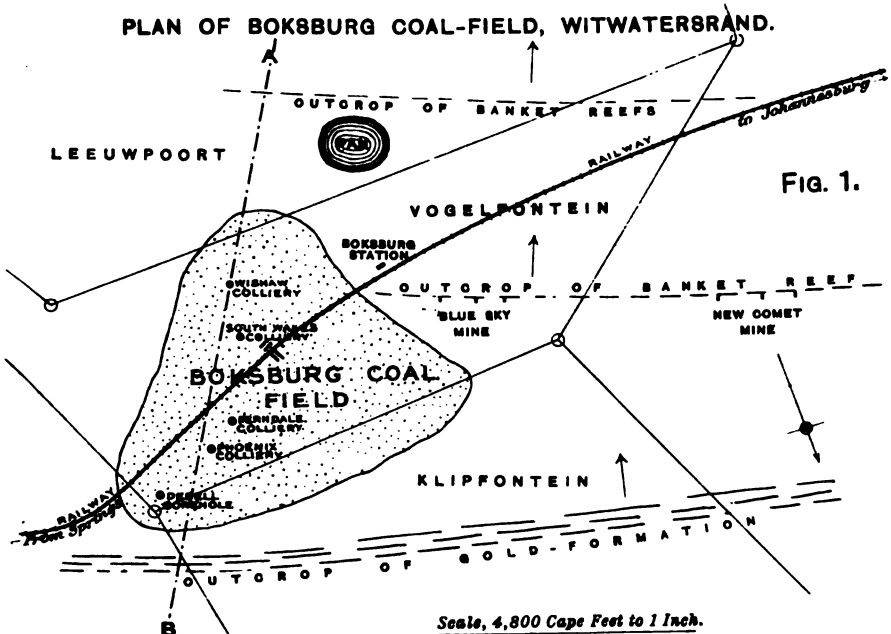
Tub-greasers are in use, and the writer can recommend them as effecting a saving both of grease used and of labour in greasing. The greasers consist of two discs revolving in a trough filled with grease, with sheet indiarubber inserted round the edge of each disc. As the tub passes over the greaser, the indiarubber presses against the bearing part of the tub-axle, and while it deposits a small amount of grease it also causes the disc to revolve a slight distance, and leaves it ready charged with grease for the next tub.

The continuous growth of the coal-trade in the Transvaal is shown by the following figures taken from the official returns :—

	Output of Coal. Tons.		Value. £		Value per Ton. s. d.		Number of Employees. Whites. Natives.		Total.
1895	... 1,152,206	...	516,215	...	8 11½	...	286 ... 3,702	...	3,988
1896	... 1,471,189	...	612,561	...	8 4	...	443 ... 5,645	...	6,088
Increase ...	318,983	...	96,346	...	0 7½	...	157 ... 1,943	...	2,100

The CHAIRMAN moved a vote of thanks to Mr. Hallimond for his valuable paper, which was cordially approved.

*To illustrate Mr. W. T. Hallimond's Notes on the Coal-Seams of the Transvaal,
and Description of a Modern Pit-head Plant."*



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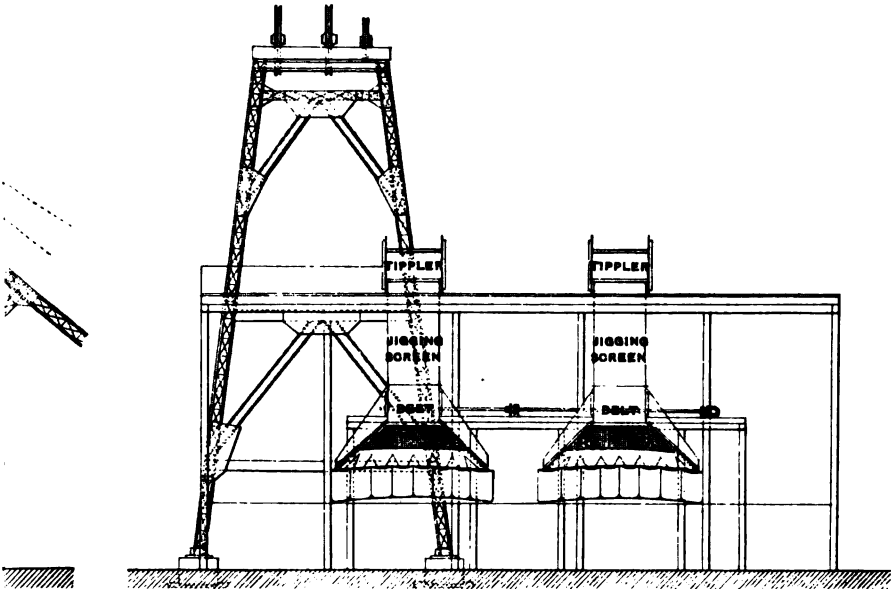
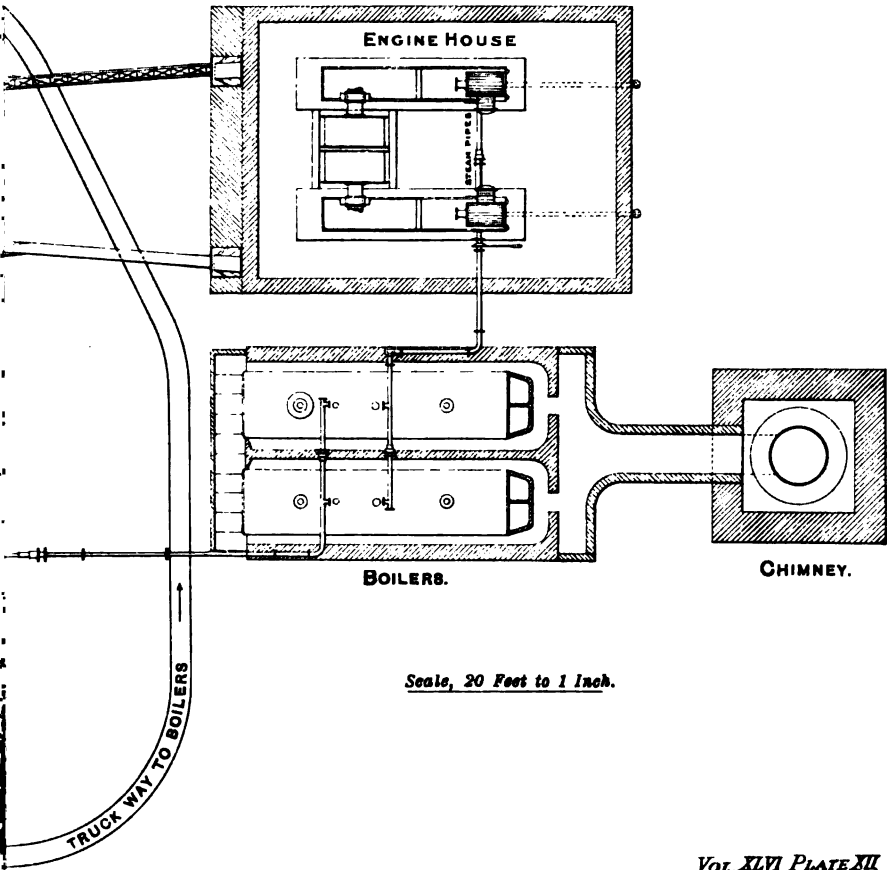


FIG. 6.—END ELEVATION.

—PLAN.



Scale, 20 Feet to 1 Inch.

DISCUSSION UPON MR. LICHTENBERGER'S PAPER ON
THE "HONIGMANN SYSTEM OF BORING AND SINKING
SHAFTS." *

Mr. M. WALTON BROWN said that Mr. W. Schulz had recently stated† that the No. 1 Pit at Heerlen, in Holland, was sunk into the Coal-measures at a depth of 830 feet on March 31st of the present year. The Coal-measures were reached at 820 feet in depth, the upper portion, 221 feet 6 inches, of the shaft had already been tubbed, and on reaching a depth of 834 feet the second section of tubing was to be inserted and wedged upon Coal-measure rocks. Immediately after this was done the sinking would be continued to the first workable coal-seam. The first section of tubing was footed firmly upon Tertiary clays. During sinking the greatest care had to be taken, as a test borehole led to the expectation that quicksand would be met with at a depth of 278 feet, and this was cut during the sinking. According to the fossils which were found in the course of sinking, it appeared to be Greensand, and was followed by a very hard Cretaceous marl. Above the Coal-measures there was a bed of clay, 10 feet in thickness.

The sinking of No. 1 pit was temporarily suspended at a depth of 224 feet, after the tubing had been inserted, as it was impossible to make it watertight against the bed of Tertiary marl on account of an accident, which had nothing to do with the Honigmann system. The sinking of this shaft will be resumed shortly. Both shafts, the uppermost 223 feet approximately in recent formations, had been sunk down to the Tertiary marl without any lining whatever, so that the Honigmann system had proved itself satisfactory. The further sinking of No. 2 pit was also carried on without any lining, and the very loose-running Greensand was pierced without any accident whatever. The pressure-water, which was still standing in the shaft, would be pumped out after the second section of tubing had been inserted and made fast upon Coal-measure rocks.

* *Trans. Fed. Inst.*, vol. xiii., page 155.

† *Hückauf*, 1897, vol. xxxiii., page 292.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND
MECHANICAL ENGINEERS.

STUDENTS' MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
JUNE 12TH, 1897.

MR. G. P. CHAPLIN IN THE CHAIR.

DISCUSSION UPON MESSRS. NOBLE AND NISBET'S "NOTES
ON COAL-MINING." *

The CHAIRMAN did not think that much coal would ever be got at the working-face by mechanical means in this district, owing to (1) the cost of the laying out of the roads, etc., which was necessary in the parts of the mines where it was intended to use coal-cutters; (2) the general unsuitability of most of the coal-seams; and (3) because the prevailing conditions of labour did not necessitate the introduction of labour-saving appliances into every possible process, as was the case in other districts. There were certainly, however, conditions in which coal-cutters could be used with distinct advantage; especially when a new district of considerable size was being opened up in coal which was not broken up by faults, and where the other conditions were favourable.

One of the costs of coal-getting that was capable of reduction was haulage, and in the manner suggested by the writers of the paper, viz., by auxiliary motors which could be easily moved and placed near the working-faces, and used for drawing the tubs to one of the main haulage-planes. He thought that electricity would undoubtedly be the power of the future, as it gave much better results than compressed air. Compressed air was said to have the advantage of supplying a certain amount of fresh air to badly ventilated mines, but he thought that it was hardly necessary in this district on that account.

* *Trans. Fed. Inst.*, vol. xiii., page 141.

Mr. A. NOBLE remarked that whether the method of working was longwall or even bord and pillar, it was difficult to see where any excessive cost would be entailed in the opening out of districts by driving the necessary roads for the introduction of mechanical coal-cutters. It was also difficult to understand why the coal-seams of this district were unsuitable for mechanical coal-cutting. The thicker seams of North-umberland and Durham would, however, in time, be exhausted, and mechanical coal-cutting would probably become profitable in thin seams of less than 3 feet in thickness.

Mr. T. E. PARRINGTON read the following paper on the "Economical Combustion of Coal for Steam-raising Purposes."

ECONOMICAL COMBUSTION OF COAL FOR STEAM-RAISING PURPOSES.

By T. E. PARRINGTON.

At the present time, when high working costs prevent substantial profits from being made, and even cause works and collieries to be laid idle, the question of how to reduce these costs as far as possible is a problem which is sure to present itself before many engineers; and although in many ways the larger items of cost have been actually reduced, or an attempt has been made to reduce them, some of the apparently smaller ones are overlooked, one of the chief of these being the cost of coals for steam-raising purposes.

The writer has lately assisted in making careful tests upon the firing of a Lancashire boiler, and wishes to show in a short paper that a very little trouble may lead the way to effecting a considerable saving in fuel.

There are two main questions to be answered before the firing of a boiler may be called satisfactory or otherwise:—(1) Is the supply of air admitted for the combustion of the coal properly regulated? and (2) what is the temperature of the gases on leaving the boiler-flues to pass into the chimney? These two conditions are, in a way, dependent upon one another; that is to say, if the temperature in the chimney-flue is found too high it will often be caused by the supply of air being too great.

(1) The first question is whether the supply of air is properly regulated, and what amount of air is being allowed per pound of coal. To regulate the air-supply, it is necessary first to know what is the theoretical amount of air required by the coal for complete combustion. The air-supply depends upon the composition of the coal; and supposing that this quantity is calculated from a chemical analysis of the coal, then an extra allowance of half as much again to twice this theoretical quantity of air should be allowed. A less quantity of air will cause incomplete combustion of the coal, and a larger quantity should not be admitted, because the surplus air deprives the coal of some of the heat created by its combustion, and if this surplus quantity be very large so much heat is taken as to render the combustion of the coal incomplete.

The next thing is to measure the allowance of air, and undoubtedly the most accurate method is to test the gases in the chimney-flue for carbon dioxide (CO_2), and by determining the percentage of the contained carbon dioxide the supply of air may, accordingly, be regulated.

In the tests made by the writer the composition of the coal was as follows :—

						Per Cent.
Carbon	...	...	...	...	...	75.0
Oxygen	...	...	...	...	...	6.6
Hydrogen	...	...	...	...	...	4.0
Nitrogen	...	...	...	...	...	2.0

To exactly burn 100 pounds of this coal, oxygen must be supplied in the following quantity :—For the 75 pounds of carbon, 200 pounds of oxygen burning into 275 pounds of carbon dioxide ; and for the 4 pounds of hydrogen, 32 pounds of oxygen burning into 36 pounds of water. The total weight of oxygen required will be 232 pounds, of which 6.6 pounds are present in the coal, leaving 225.4 pounds to be derived from the air-supply, and with this nitrogen will enter in the proportion of 23 pounds of oxygen to 77 pounds of nitrogen, or 754.6 pounds of nitrogen. The total weight of air required will be 980 pounds, or say, 10 pounds of air per pound of coal.

The composition of the chimney gases will be :—

				Pounds.	Per Cent.
Carbon dioxide, CO_2	...	...	...	275.0	28
Water, H_2O	...	...	...	36.0	3
Nitrogen, from air, N	...	...	...	754.6	71
„ from coal	...	...	...	2.0	
Total	...	...	...	1,067.6	100

That is to say, if 100 pounds of this coal were burnt with the exact theoretical amount of air necessary for combustion, the carbon dioxide would form about 28 per cent. of the resulting gases.

But, as has been above stated, coal cannot be burnt in a boiler-fire unless from half as much again to twice this amount of air is admitted. Let us suppose that 15 pounds of air are being supplied per pound of coal ; then if coal be burnt with this allowance the carbon dioxide is found from the analyses of the gases to be 17 per cent. of the flue-gases, or if the maximum (20 pounds) of air be allowed per pound of coal, the gases will be found to contain only $13\frac{1}{2}$ per cent. of carbon dioxide, the percentage of carbon dioxide decreasing as the excess of air increases.

These calculations show that it is only necessary to know the percentage of carbon dioxide in the flue-gases, in order to find what quantity of air is being supplied to the coal-fires.

The apparatus used by the writer for testing the flue-gases for carbon dioxide was the Schloesing (Fig. 1), which is very similar to the, perhaps better known Orsat apparatus.

A glass or porcelain pipe is inserted for some distance downwards into the chimney-flue, and connected with the apparatus at *A*; the other end *D* is connected to an aspirator; by means of a pipette a small drop of mercury is run into the bulb *V*, which will act as a valve; the reservoir *R* is filled with mercury until it rises to the point *B* in the measuring-vessel *M*; and caustic-potash-solution is poured into *S*, until it fills the spiral, and rises about 1 inch upwards into the tube *C*. The various

parts must now be connected with indiarubber tubing, and the apparatus is ready for the sample of gas.

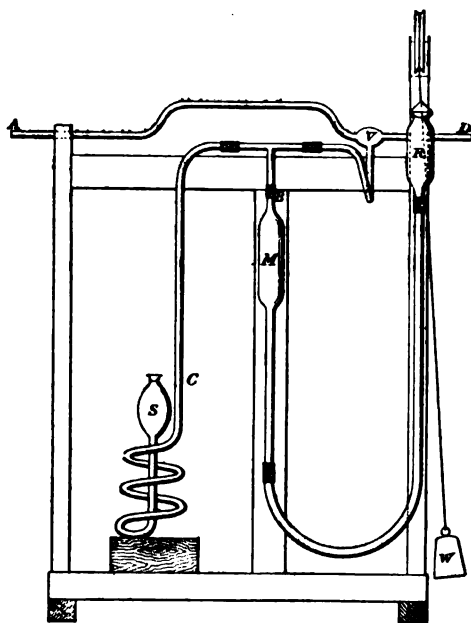


Fig. 1.

To obtain a sample of gas, open the aspirator and run out about 1 quart of water, then by raising the weight *W*, allow *R* to fall slowly, until the mercury in *M* drops to zero; in this way a sample of gas is drawn into the measuring-vessel *M*; the valve *V* is then closed, and the level of the caustic-potash solution in the tube *C* is noted. Then, by raising *R* again, cause the mercury to rise into *M*, and as the valve is closed,

the gas will be forced into the caustic-potash solution, where the carbon dioxide will be absorbed. After waiting a few minutes, the gas must be passed back into the measuring-vessel until the caustic-potash solution returns to its first reading. Then, the decrease of volume of the gas in *M* will show the percentage of carbon dioxide contained in the flue-gases. To ensure that all the carbon dioxide is absorbed, it is desirable to return the gases into the caustic-potash solution, and take a final reading. When this is done, open the valve *V*, and raise *R* so that the gas may pass out into the air, and the apparatus will be ready for the testing of another sample.

Care must be taken not to insert the pipe into the flue, too near the damper or beyond it, as more or less air is always sure to enter the flue between the damper and the brickwork, causing the percentage of carbon dioxide to be smaller than it actually is. The boiler-seating, flues and all brickwork should be in good order, and not leaking.

In the way described above, the carbon dioxide can be measured, and as has been shown, from $13\frac{1}{2}$ to 17 per cent. would indicate economical firing with this coal. In order to illustrate the waste that may so easily occur, suppose that the percentage of carbon dioxide was found to be only 5 per cent. This percentage shows that the supply of air is at the rate of more than 50 pounds per pound of coal, whereas an allowance of 20 pounds is the maximum in this case, so that 30 pounds of excess-air are being heated by every pound of coal burnt. And as the coal used to heat this excess-air would, if the air had not been admitted, have imparted its heat to raising the temperature of the water in the boiler, this heat, and consequently the coal which yields it, is being wasted.

(2) The second question is to determine the temperature of the flue-gases when they leave the boiler and pass into the chimney.

The minimum and maximum temperatures allowable are 400° Fahr. and 600° Fahr. respectively—a temperature lower than 400° Fahr. is seldom found; but if it be below this, a slackness of chimney-draught will soon result, while the more likely mistake of having too high a temperature will cause a loss of generated heat, and a consequent waste of coal.

There are numerous kinds of pyrometers, and the writer does not intend to describe any of them here. The one that he used is known as the Siemens water-pyrometer or Siemens copper-ball pyrometer, and it is one which can be relied upon to give very accurate results. The using is certainly rather a lengthy process; but while the dial-pyrometer is easier to use, it is very apt to get out of order.

Now, supposing the temperature of the flue-gases is found to be $1,000^{\circ}$ Fahr., instead of 500° Fahr., what is the extent of the consequent waste?

The British thermal units of heat derived by burning 100 pounds of the same coal will be :—

	British Thermal Units.
Carbon, 75 pounds by 14,545 units	 = 1,090,875
Hydrogen, 4 pounds — 6.6 pounds $\div$ 8, by 62,032 units	= 196,952
Total heat units	 = 1,287,827

And the heat wasted in British thermal units by the gases escaping at $1,000^{\circ}$ Fahr. instead of 500° Fahr. will be, with a minimum excess of air:—

	Pounds.		Excess Temperature.		Specific Heat.		British Thermal Units.
Nitrogen ...	1,133·9	x	500°	x	0·244	—	138,335·8
Oxygen ...	112·7	x	500°	x	0·217	—	12,227·9
Carbon dioxide	275·0	x	500°	x	0·217	—	29,837·5
Water-vapour	36·0	x	500°	x	0·480	—	8,640·0
Total heat units wasted							— 189,041·2

Approximately, one-seventh of the heat produced is wasted; and if the maximum quantity of air had been allowed, the waste would have been still greater. As it is, 1 ton of coal might have been saved in every 7 tons used, and by the end of a year, with, say, 6 boilers, this loss of coal would represent a very considerable sum of money.

But the point may be raised by steam-users that, if these conditions are observed—the air properly regulated, and the flue-gases kept at, say, 500° Fahr.—the full work cannot be got out of the boiler. This objection raises the important question: does it pay to keep, say, 5 boilers at work and force them, or to use 6 boilers and work them quietly, saving the difference of coal?

Taking 5 boilers at 7 tons of coal per 24 hours, or 35 tons per day, and allowing a minimum of air, say, 15 pounds per pound of coal, and the flue-gases escaping at 1,000° Fahr. instead of 500° Fahr., then one-seventh of this coal will be wasted, or 5 tons per day.

The 6 boilers would use, under proper treatment, 30 tons of coal for the same work that 5 boilers used 35 tons. The saving of coal will be 5 tons by 365 days, or 1,825 tons per year, and this quantity, at 6s. per ton, represents an annual saving of £547 10s.

The sixth boiler, with its seating and share of chimney cost, may be reckoned at £600; and allowing 4 per cent. interest on capital, and 7½ per cent. for redemption, the charge will be £69 per annum.

The net saving will be (annual saving of fuel, £547 10s., less the extra charge for the extra boiler, or £69) £478 10s. per annum. Consequently, the sixth boiler would repay its cost in 1½ years, and in addition it should not be forgotten that whereas 5 boilers would be forced, 6 boilers would work quietly, and would have longer lives.

The CHAIRMAN moved a vote of thanks to Mr. Parrington for his practical paper, which was cordially agreed to.

MIDLAND INSTITUTE OF MINING, CIVIL, AND
MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE HARVEY INSTITUTE, BARNSELY, MARCH 27TH, 1897.

MR. G. B. WALKER, PRESIDENT, IN THE CHAIR.

Mr. E. W. THIRKELL read the following paper on "Adequate Ventilation and Noxious Gases" :—

ADEQUATE VENTILATION, AND NOXIOUS GASES : WITH
SPECIAL REFERENCE TO THE RECOMMENDATIONS
OF THE ENGLISH, FRENCH, PRUSSIAN, AND AUSTRIAN
FIRE-DAMP COMMISSIONS.

By E. W. THIRKELL.

The following extracts are taken from the General Rules of the Coal Mines Regulation Act, 1887, and form the basis of the subjects treated in this paper :—

(1) *Ventilation*.—An adequate amount of ventilation shall be constantly produced in every mine to dilute and render harmless noxious gases to such an extent that the working-places of the shafts, levels, stables, and workings of the mine, and the travelling roads to and from those working-places shall be in a fit state for working and passing therein.

(2) Where a fire is used for ventilation the return air, unless it be so diluted as not to be inflammable

(7) *Dangerous Places*.—If at any time that by reason of inflammable gases prevailing in the mine the mine or that part is dangerous if the danger arises from inflammable gas, shall inspect the mine or part with a locked safety-lamp and a workman shall not, except in so far as is necessary for enquiring into the cause of danger, or for the removal thereof, or for exploration, be readmitted until the same is stated not to be dangerous.

(8) *Naked Lights*.—No lamp or light other than a locked safety-lamp shall be allowed or used—(a) In any place in a mine in which there is likely to be any such quantity of inflammable gas as to render the use of naked lights dangerous.

(9) *Safety-lamps*.—Wherever safety-lamps are used they shall be so constructed that they may be safely carried against the air-current ordinarily prevailing in that part of the mine in which the lamps are for the time being in use, even though such current should be inflammable.

The writer has prepared this paper in the belief that an investigation into the interpretation of these rules would be interesting to the members.

(I.) *An Adequate Amount of Ventilation.*

(a) *Respiration of Men.*—The respirations of healthy persons from 25 to 30 years of age average 16 per minute. The act of inspiration occupies longer than that of respiration in the ratio of 12 to 10 in adult males. The quantity of air which the lungs take in at each inspiration is on an average 34 cubic inches when the person is at rest. So that (34 cubic inches $\times$ 16 or) 544 cubic inches of air are required per minute. Dr. J. S. Haldane, in his report,* states that “100 cubic feet of air would suffice to keep a man alive for 10 hours.” This volume is only at the rate of 288 cubic inches per minute, so that the air would be breathed twice over ($544 \div 288$). Prof. F. Clowes states that† “the same air might be breathed in again and again three or four times before it became inconvenient or uncomfortable to breathe.”

In breathing, about 4 per cent. of carbon dioxide is given off from the lungs, consequently a person would exhale (4 per cent. of 544 cubic inches or) 21.76 cubic inches per minute. Ordinary air contains 0.04 per cent. of carbon dioxide, so that a man vitiates it to the extent of (21.76 cubic inches $\div$ 0.04 or) 544 cubic inches; consequently 544 cubic inches of fresh air will be required to purify that vitiated, in addition to the 544 cubic inches required for breathing, or (544 + 544 or) 1,088 cubic inches per minute for ordinary breathing; but the atmosphere is also made unhealthy by the poisonous addition of effete or refuse material which is being constantly exhaled from the lungs and skin of men and horses—especially when hard at work. The impurity in the air varies according to the space per individual, and it is not desirable to have many men and horses working close together. Each adult requires about 1,000 cubic feet of space for healthy breathing.

In order to arrive at an estimate of the extra quantity of air required when the men and horses are working, the following figures have been adopted, in the absence of more reliable information:—

If the air inspired in a lying position be taken as unity, then the air inspired in a sitting position may be taken at 1.18; when walking 1 mile an hour, at 1.9; 3 miles an hour, at 3.22; and 6 miles an hour, at 7.00. Walking at the rate of 1 mile an hour is equal to $17\frac{1}{2}$ foot-tons of energy, and at 4 miles an hour, to 70 foot-tons; a man's ordinary work

* *Causes of Death in Colliery Explosions*, 1896, page 33.

† *Trans. Fed. Inst.*, vol. ix., page 389.

is equal to 300 foot-tons, and very hard work to 403 foot-tons. So that lying down being taken as unity, an ordinary day's work would be equal to about 32, and as a person at rest requires 1,088 cubic inches of fresh air per minute, he would require $(1,088 \text{ cubic inches} \times 32 \text{ or})$ 34,816 cubic inches, or about 20 cubic feet per minute when working.

(b) *Respiration of Horses.*—An average horse respires 12 times a minute (when at rest), and about 250 cubic inches will be expired at each respiration, of which 4·7 per cent. will be carbon dioxide. A horse at rest therefore requires $(12 \times 250 \text{ cubic inches or})$ 3,000 cubic inches per minute for breathing, and of this 4·7 per cent. is carbon dioxide, or 141 cubic inches is converted into carbon dioxide, and it will require $(141 \text{ cubic inches} \div 0\cdot04 \text{ or})$ 3,525 cubic inches per minute to purify it; a horse therefore requires 3,000 cubic inches for breathing, and 3,525 cubic inches in addition to purify that breathed, making 6,525 cubic inches of air per minute altogether.

Pit-horses and ponies are generally much less than those employed on the surface, and for the purpose of this paper it will be desirable to deduct 25 per cent. from the above result; leaving 4,894 cubic inches of air required for a pit-horse when at rest, and $(4,894 \text{ cubic inches} \times 32 \text{ or})$ 156,608 cubic inches, or say 90 cubic feet of air per minute when working.

(c) *Combustion of Lamps.*—In an experiment, a safety-lamp, enclosed in an air-tight vessel of 489 cubic inches capacity, used the air in 3 minutes, or at the rate of 163 cubic inches per minute. One-fifth of the air would be used up in burning, so that $(163 \text{ cubic inches} \div 5 \text{ or})$ 32·6 cubic inches of air would be used per minute. Then $(163 + 32\cdot6 \text{ or})$ 195·6 cubic inches would be required per minute, of which 3 per cent. would be carbon dioxide, or $(195\cdot6 \text{ cubic inches} \times 3 \text{ per cent. or})$ 5·868 cubic inches, and to restore the air thus vitiated to its normal state would require $(5\cdot868 \text{ cubic inches} \div 0\cdot04 \text{ or})$ 146·7 cubic inches; and $(195\cdot6 + 146\cdot7 \text{ or})$ 342·3 cubic inches of fresh air per minute. The air vitiated, however, depends upon the quality of oil used, as some oils (benzolene) require a smaller volume of air to produce perfect combustion than others (rape oil).*

It has thus been shown that a man at work requires 20 cubic feet, a horse at work 90 cubic feet, and a lamp 342·3 cubic inches ($\frac{1}{2}$ cubic foot) of fresh air per minute, for ordinary purposes.

* *Trans. Fed. Inst.*, vol. ii., page 355.

(II.) *Gases.*

It is necessary now to consider what quantity of air, in addition to the above, is required in respect of the gases met with in the mine. For a description of the gases, the writer has chiefly referred to Dr. Haldane's *Report on the Causes of Death in Colliery Explosions*, etc.,* as being, to some extent, official.

Carbon Dioxide or Carbonic Acid (Choke-damp).—In breathing air containing increasing proportions of carbon dioxide, the first distinct effects are felt with about 3 or 4 per cent. The respirations become somewhat deeper, but nothing further is experienced. . . . With about 6 per cent. there is distinct panting. At the same time slight frontal headache may be felt. . . . At 7 or 8 per cent. the panting is very distressing, especially at first; and with 10 or 11 per cent. the respiratory distress is extreme. . . . 15 per cent. . . . extinguishes lights.†

Table I. gives a summarized result of the effects.

TABLE I.‡

Percentage of Carbon Dioxide present		Effects on Man	Effects on Lights.
3·5	...	Breathing deeper	Still burns.
6·0	...	Marked panting	„
10·0	...	Severe distress...	„
15·0	...	Partial loss of consciousness...	Extinguished.
25·0	...	Final death	„

Oxygen and Nitrogen.—When the oxygen percentage of air is gradually reduced by absorption of the oxygen, or (what is exactly the same thing) by addition of nitrogen, very little may be felt before the occurrence of impairment of the senses and loss of power over the limbs.§

Table II. shows the effects on man and lights.

TABLE II.||

Percentage of Oxygen present.		Percentage of Nitrogen present.		Effects on Man.	Effects on Lights.
17·3	...	82·7	...	Nil	Extinguished.
12·0	...	88·0	...	Breathing slightly deeper	„
9·0	...	91·0	...	Breathing deeper and more frequent. Face bluish	„
5·0	...	95·0	...	Loss of consciousness and final death	„
0·0	...	100·0	...	Death, with convulsions	„

Black-damp.—Black-damp is not a pure gas, but a mixture containing about 87 per cent. of nitrogen and 13 per cent. of carbon dioxide. The dangers to life arising from black-damp evidently depend on the reduction which it causes in the oxygen percentage of the air. . . . Before any real danger can occur, the car-

* Also *Detection and Estimation of Inflammable Gas and Vapour in the Air*, by Prof. Clowes, page 18.

† *Causes of Death in Colliery Explosions*, page 15.

‡ *Ibid.*, Table I., page 21. § *Ibid.*, page 15. || *Ibid.*, Table I., page 21.

bonic acid will, by causing severe panting, have given distinct warning of the impending danger. . . . Excess of carbonic acid produces panting far more rapidly than does a corresponding deficiency of oxygen. . . . With carbonic acid the panting begins long before there is serious danger, while panting from deficiency of oxygen hardly occurs until danger is imminent. The presence of the carbonic acid in black-damp thus gives a valuable and timely warning of approaching danger. . . . An atmosphere which has been rendered just distinctive to lamps from admixture with nitrogen or black-damp is harmless to men. In case of urgent necessity, a man may penetrate without harm into an atmosphere containing four times as much black-damp as would extinguish a lamp.*

Table III. exhibits the effect on man and lights.

TABLE III.†

Percentage of Black-damp (containing 87 per cent. of Nitrogen and 13 per cent. of Carbon Dioxide) present.		Effects on Man.					Effects on Lights.
16	...	Nil	...	...	...	...	Extinguished.
28	...	Breathing slightly deeper	...	...	...	...	"
50	...	Severe panting	...	...	...	...	"
66	...	Life endangered	...	...	...	...	"

Fire-damp.—The action on man of methane or fire-damp is exactly the same as that of nitrogen. . . . Fire-damp only acts by diluting the oxygen of the air. It follows from this that air containing as much as 50 or 60 per cent. of fire-damp may be breathed for a time without harm.‡

Table IV. exhibits the effects of fire-damp or methane.

TABLE IV.§

Percentage of Fire-damp present.		Effects on Man.					Effects on Lights.
1·0	...	Nil	...	...	...	...	First indication of a cap.
2·0	...	"	...	...	...	...	Well-formed cap.
5·5	...	"	...	...	...	...	Lamp fires and goes out.
45·0	...	Breathing slightly deeper	...	...	...	...	" "
70·0	...	Life endangered.	...	...	...	...	

Sulphuretted Hydrogen.—It occasionally happens that fire-damp is mixed with traces of sulphuretted hydrogen. This is easily recognized by the smell of rotten eggs. Sulphuretted hydrogen is excessively poisonous; as little as 0·1 per cent. will cause rapid loss of consciousness and death. Smarting of the eyes and catching of the breath are signs of imminent danger from this gas.||

This gas is generated by the putrefaction of animal matters; also by the de-oxidation of sulphates in presence of decaying organic matter; it is a product of the explosion of gunpowder, and of the decomposition of iron pyrites; it also is found in old workings with standing water.

* *Causes of Death in Colliery Explosions*, page 16.

† *Ibid.*, Table II., page 21.

‡ *Ibid.*, page 16.

§ *Ibid.*, Table II., page 21.

|| *Ibid.*, page 16.

Carbon Monoxide.—The symptoms produced by it [carbon monoxide] are . . . due to partial or complete absence of oxygen in the air breathed . . . with 0·2 per cent. [in the air] . . . complete helplessness, with loss of consciousness would doubtless occur . . . 0·30 per cent. would certainly cause death in time . . . Many lives have been lost through ignorance of the fact that the lamps . . . give no direct indication of carbon monoxide. Like other explosive gases, it shows a cap on an ordinary flame if present in a higher proportion than about 1 per cent., but in after-damp and gob-stink carbon monoxide always occurs in combination with such an excess of nitrogen that the lamp is extinguished before it can show a cap . . . when more than 16 per cent. of after-damp, or about 0·5 per cent. of carbon monoxide is present, a lamp will be extinguished. Hence the indications of a lamp will, at least, prevent a man from going into an atmosphere which is very rapidly poisonous from carbon monoxide.*

Table V. exhibits the effects of carbon monoxide.

Percentage of Carbon Monoxide present.		TABLE V.†		Effects on Lights.	
		Effects on Man.			
0·05	...	After ½ hour or more, slight giddiness on exertion		...	—
0·10	...	After ½ hour or more, inability to walk		...	—
0·20	...	After ½ hour or more, loss of consciousness and perhaps final death ...		...	—
1·00	...	After a few minutes, loss of consciousness and final death		...	Cap.‡

After-damp.—After explosion, the hot after-damp would consist of:—

Nitrogen	...	...	...	...	70·71	} 71·55
Argon	...	...	...	...	0·85	
Carbonic acid	...	...	...	...	...	9·50
Aqueous vapour	...	...	...	...	...	18·95

100·00§

After-damp might cause death either from deficiency of oxygen or from the presence of carbon-monoxide. If the after-damp were quite free from air or oxygen, it could make no difference whether carbon-monoxide were present or not, since carbon-monoxide has the same action as deficiency of oxygen.||

Table VI. exhibits its effects on man and lights.

Percentage of After-damp (containing 3 per cent. of Carbon Monoxide) present.		TABLE VI.¶		Effects on Lights.	
		Effects on Man.			
2·0	...	After ½ hour or more, slight giddiness on exertion		Nil.	
3·5	...	Inability to walk		,,	
7·0	...	Loss of consciousness		,,	
10·0	...	Death		Burns rather dimly.	
16·0	...	,, ...		Extinguished.	

* *Causes of Death in Colliery Explosions*, pages 17 and 19.

† *Ibid.*, Table I., page 21. ‡ *Ibid.*, page 19. § *Ibid.*, page 8.

|| *Ibid.*, page 22. ¶ *Ibid.*, Table II., page 21.

Sulphurous Acid.—It seems probable that sulphurous acid is present in after-damp, and causes the well known irritation of the eyes and air-passages. . . . As little as 0·001 per cent. produces slight irritation of the respiratory passages. With 0·003 per cent., the symptoms of irritation are very marked. . . . About 0·01 per cent. was sufficient to cause death after some time. Sulphurous acid is thus an exceedingly poisonous gas; but the symptoms of irritation caused by it seem to occur long before there could be any danger to life. Its presence in after-damp therefore affords a valuable indication of danger.*

Fire-damp.—Fire-damp will now be considered, as being the principal inflammable gas referred to in the General Rules. What quantity or percentage is inflammable and will render the use of naked lights dangerous?

Mr. A. H. Stokes, in his evidence respecting the Blackwell explosion, said that "2 per cent. was safe with a naked light: he should not consider 2 per cent. dangerous, though it would require watching. An ordinary safety-lamp would show 8 per cent. of gas."

Prof. F. Clowes states that, when air contains less than 5 per cent. of fire-damp, it cannot be fired by a flame unless it is also mixed with a large amount of fine suspended coal-dust.† Messrs. Mallard and Le Chatelier give 5·6 and 6 per cent., whilst the English Commissioners' Report states that "our experiments with lamps in gas mixtures have led us to the conclusion that when little more than 4 per cent. of marsh gas is present, flame may be transmitted under circumstances which occur in a mine."‡

The Prussian Fire-damp Commissioners made some experiments in 1887 with a naked light let down into a chamber filled with gas in varying proportions, and it was not until the mixture contained 6 per cent. of gas that the "phenomenon produced the impression of an explosion," and then comparatively feeble. They state "it would appear, therefore, that mixtures containing from 4 per cent. to 6 per cent. of marsh gas are by no means so dangerous as is generally supposed."§

The French Fire-damp Commission say that "with 6½ per cent., a feeble explosion occurred repeatedly."¶

It is important to remember that "fire-damp" so called, is not always composed of precisely the same constituent parts; this variation of com-

* *Causes of Death in Colliery Explosions*, page 21.

† *Colliery Manager*, 1897, page 20.

‡ *Final Report of Commissioners on Accidents in Mines*, page 19.

§ *Trans. Fed. Inst.*, vol. iii., page 1144.

¶ Ignition by electric sparks with 10 per cent. to 12 per cent. of gas; by heated wires, 10 per cent., *ibid.*, vol. iii., page 1145. Ignition by friction of hard rocks by breaks in the roof., *ibid.*, vol. iv., page 679.

¶ *Report of French Commission*, page 5.

position will account for the fact that sometimes it is more readily ignited in a safety-lamp than at other times.*

Prof. Dixon's excellent paper throws much light upon this subject.†

(III.) *Coal-dust.*

The presence of very fine coal-dust in the air appears to completely alter the state of things. But here again opinions differ.

According to the English Commission ‡ explosions were produced by dust suspended in air travelling at a velocity of 600 feet per minute, when fire-damp was present in proportions ranging from 2 to 2·75 per cent.; in currents of low velocity the same result was produced with a sensitive dust in the presence of 1·5 per cent.

According to the French Commission,§ with mixtures of air, coal-dust, and fire-damp, nothing occurred when the mixture only contained 4 per cent. of fire-damp; when this proportion was exceeded, an unsteady flame existed for some seconds, very feeble, bluish or yellowish. With 6½ per cent. a feeble explosion occurred repeatedly.

According to the Prussian Commission,|| in ordinary atmospheric air all varieties of coal-dust are found harmless in the presence of naked lights. Even when this air contains as much as 4 per cent of methane, this harmless character is maintained. If the air contains 4·5 per cent. or more, certain varieties of coal-dust will induce an explosion in the presence of naked lights. At a proportion of only 5 per cent. of methane this explosion is incomparably more violent than is the case without coal-dust of 6 per cent. of methane.

According to Mr. W. Galloway, under suitable conditions a mixture of air with fine coal-dust and containing only 1 per cent. of fire-damp can be fired and give rise to an explosion.

Dr. J. S. Haldane says :—

It is well known that coal-dust has a marked power of absorbing gases, so that any gas or vapour found in small proportions may easily be taken up by the suspended dust.¶

It seems not unlikely . . . that such measures as the removal of excess of dust and the moderate or partial watering so elaborately carried out in many mines may increase rather than diminish the chances of a dust explosion. **

* "Mining Explosives," by Mr. Vivian B. Lewes, *Trans. Fed. Inst.*, vol. ix., page 324.

† "Rate of Explosion in Gases," by Prof. H. B. Dixon, *Trans. Fed. Inst.*, vol. viii., page 314.

‡ *Op. cit.*, page 35. § *Op. cit.*, page 5.

|| *Trans. Fed. Inst.*, vol. iii., page 1140, etc.

¶ *Causes of Death in Colliery Explosions*, page 26.

** *Ibid.*, page 25.

Probably the most dangerous coal-dust is that obtained from the screens, and the writer is of opinion that much can be done to prevent this dust from going down the downcast shaft by watering the pit-hills, and by "sprayers" playing upon the coal as it comes from the "tipplers," and also by the use of sprayers in the shaft itself, by which the dust would be saturated with moisture, and would get no farther than the sump-boards, etc., in the pit-bottom, instead of being carried in-bye, as is the case at many collieries.

It seems improbable that a mixture of coal-dust and 4 per cent. of fire-damp is dangerous if the air be comparatively still, like it is in an ordinary working-place, but if vibration be set up (by a blown-out shot for instance) then the circumstances are altered.* The flame from a blown-out shot would heat the coal-dust, which would give off its gas by distillation, and would become inflamed; this in turn would heat more dust, when the same thing would occur, and so an explosion would be brought about without any gas at all, except that given off by distillation. It requires much less heat to explode the gas which is given off by distilled coal than to explode fire-damp.

(IV.) *Safety-lamps.*

Ordinary safety-lamps will not indicate the presence of fire-damp unless it amounts to $2\frac{1}{2}$ or 3 per cent. of the mixture, but this depends to a very great extent upon the lamp and the illuminant used. With an oil flame, gas can only be detected when the proportion is about 3 per cent.; but with a benzoline flame, the caps will indicate percentages as low as 1.5 per cent.

The English Commission, already referred to, recommend the bonneted class of safety-lamp. They recommend that all safety-lamps should be provided with a shut-off appliance for the extinction of the flame produced by both the illuminants and by ignited gas within the lamp; also that in the case of bonneted lamps there should be two vertical slits at opposite sides to enable the miner to see that the gauze was in the lamp.

The lamp fixings should also be so arranged that it is impossible to put a lamp together unless every part is in its proper place.

Speaking of lamps, too, it would be out of place if the writer did not refer to the excellent work done by the Institute, under the superintendence of Mr. C. E. Rhodes, in their most elaborate experiments with safety-lamps in 1883 and 1884. That committee especially pointed out

* "Mining Explosives," by Mr. Vivian B. Lewes, *Trans. Fed. Inst.*, vol. ix., page 320.

the value of the bonnet over an exposed gauze, and that all safety-lamps fed with air from above the flame and provided with this protection are safer than any other.

Having got a lamp of the approved type, such lamp should be tested with varying mixtures of gas and air, in order to see what height of cap, on a given sized flame, would be produced with the illuminant in use at the colliery. In this case a deputy could report the amount of gas, according to a scale, which could be fitted to the lamp, in the same way as he reports the water-gauge.

The Pieler gas-testing lamp will indicate $\frac{1}{4}$ per cent. of fire-damp, and fires with $1\frac{1}{2}$ per cent.* Prof. F. Clowes' hydrogen lamp will also indicate $\frac{1}{4}$ per cent.

Mr. J. L. Hedley thinks that there should be some governing regulations, even if these delicate instruments were used, fixing the percentages of gas beyond which the miner should not be allowed to work.†

The protector Mueseler lamp, with gas-oil, when tested with Prof. F. Clowes' hydrogen lamp showed $1\frac{1}{2}$ per cent. of gas, with a cap $\frac{1}{4}$ inch high on $\frac{1}{4}$ inch blaze, whilst a Davy safety-lamp, according to Mr. W. Galloway's experiments, only showed $\frac{1}{4}$ inch cap for $2\frac{1}{2}$ per cent. of gas.

Probably the percentages of gas for given sized caps in the protector Mueseler lamp, with gas-oil, on $\frac{1}{4}$ inch blaze or flame would be as follows :—

					Inches.
For $1\frac{1}{2}$ per cent. of gas, a cap of	...	...	...	...	0·250
„ $2\frac{1}{2}$ „ „	...	...	...	...	0·375
„ 3 „ „	...	...	...	...	0·562
„ 4 „ „	...	...	...	...	1·187

The temperature of the air, at the place where the test is being made, is important, because the inflammability of combustible gases decreases with diminishing temperature. Further, it is possible that the retardation in the ignition of fire-damp may diminish with the increase in the quantity of aqueous vapour contained in the air.‡

Every lamp should be tested regularly in an explosive gas mixture before it is given out to the workmen.

(V.) *Summaries of the Reports of Royal Commissions.*

Austrian Report.§—The velocity of air in the shaft should not exceed 20 feet a second, or 33 feet per second if the shaft be used for ventilation

* *Trans. Fed. Inst.*, vol. x., page 556.

† *Ibid.*, vol. viii., page 169.

‡ *Report of French Commission*, page 32.

§ *Trans. Fed. Inst.*, vol. iii., page 542.

only. The return air should be calculated to exceed the intake in volume by 15 per cent.

The sectional area of the roads should be such that the required amount of ventilation can be conveyed at a velocity not exceeding 20 feet per second; the space occupied by curves, etc., should be allowed for in this calculation.

The ventilation should be such that the return air does not contain more than $1\frac{1}{2}$ per cent. of fire-damp, and $\frac{1}{2}$ per cent. of carbon dioxide, or altogether 2 per cent. For this purpose the quantity of air required is as follows:—Class I.—Mines producing little fire-damp (less than 1 per cent. of $\text{CH}_4 + \text{CO}_2$ in the return air), at least 70 cubic feet of air per man per minute, calculated on the largest shift, and counting a horse equal to four men. Class II.—Mines producing a moderate amount of fire-damp (1 to 2 per cent. of $\text{CH}_4 + \text{CO}_2$ in the return air), at least 105 cubic feet per man per minute. Class III.—Mines producing much fire-damp (more than 2 per cent. of $\text{CH}_4 + \text{CO}_2$ in the return air), at least 140 cubic feet per man per minute.

Not more than 100 workmen should be employed on one split of air.

In collieries, where there are large areas of old workings (goafs), the proportion of fire-damp faithfully followed the barometrical curve, but in existing workings it made no difference.

*Prussian Report.**—The velocity of the air in the downcast shaft shall not exceed 800 feet per minute, and in the upcast shaft shall not exceed 1,200 feet per minute.

The velocity of the air in the main intake airways shall not exceed 787 feet per minute, and in the main return airways, 1,181 feet per minute. High velocities are condemned, and airways should be enlarged to allow of a low velocity. Main airways should not be less than 32.29 square feet in area; branch airways, 21.52 square feet, and slits, etc., 10.76 square feet.

The volume of fresh air must amount to at least 70.62 cubic feet per head per minute, on the maximum number of workmen employed underground in the course of one shift. A horse is reckoned as the equivalent of four men. Further, the volume of fresh air per minute which should be supplied in a fiery mine must in each independent ventilating district amount to 52.95 cubic feet per ton of average daily output, and the gaseous content of the return air-current must be reduced to 1.5 per cent.

* *Trans. Fed. Inst.*, vol. iii., page 1105; vol. iv., page 631; and vol. v., page 500.

Some experiments were made in pillar workings to ascertain the amount of gas given off in working the coal, with the following result :— In the first, or whole working, the amount was 812 cubic feet of gas per ton of coal, and 33 cubic feet per square foot of surface exposed ; in the passage from whole work to pillar work, 1,221 cubic feet of gas per ton of coal and 16 cubic feet per square foot of surface exposed ; and in pillar working, 550 cubic feet per ton of coal. Investigations have shown, with few exceptions, a considerable reduction in the proportion of marsh gas in the airways on Sundays as against working days—in one case 2,446 cubic feet per hour on a Sunday, against 4,157 cubic feet on a Tuesday with 727 men at work.

English Commission on Accidents in Mines.—No fixed quantity of air per man, or per ton, is recommended. In Appendix XVIII., a table is given of the velocity of the air in coal-mines. From this table it appears that in shafts the velocity is sometimes as much as 6,032 feet per minute (upcast), and in an airway 3,825 feet per minute. The average appears to be about 1,300 feet per minute in main return airways, about 1,000 feet per minute in main intake airways, and about 270 feet per minute in the working-places. A workman does not like to work in a draught, and a velocity of anything over $2\frac{1}{2}$ feet per second will cause this. Probably a good working velocity would vary from 120 to 180 feet per minute.

Mine-law of Pennsylvania, U.S.A.—Ample means of ventilation must be provided, affording not less than 150 cubic feet per minute for each and every person employed. Not more than 100 persons shall be permitted to work in the same air-current.

New South Wales, Coal Mines Act, 1896.—Not less than 100 cubic feet of fresh air per minute shall be provided for each man, boy, and horse employed in the mine. Not more than 70 persons may be employed in one split or air-current.

(VI.) *Explosives used in Mines.*

The gases produced by the detonation of 7 ounces of gunpowder measure 1·92 cubic feet, and have the following composition* :—

	Per Cent.	Cubic Feet.
Carbon dioxide	49·9	0·95808
Carbon monoxide	14·1	0·27072
Nitrogen	33·3	0·63936
Sulphuretted hydrogen	2·7	0·05184

* *Trans. Fed. Inst.*, vol. ii., page 378.

To become harmless, the carbon dioxide must be reduced to 1 per cent., the carbon monoxide to 0.02 per cent., the nitrogen increased to 77.95 per cent., and the sulphuretted hydrogen reduced to 0.02 per cent.

Consequently (2,572 cubic feet of air $\div$ 1.92 or) 1,339 times the volume of the gases given off by the explosion of the gunpowder will be required. According to the composition given by Mr. Orsman at a recent lecture, his figures being somewhat different from the above, 1,347 times the volume of the gases given off by the explosion of the gunpowder will be required. In a place, where a shot was fired with 188 cubic feet of air passing per minute, it took 12 minutes to make it clear, and 2,256 cubic feet of air were required as against 2,572 given above.

In the report on "An Investigation as to whether the Fumes," etc. * (from which the composition of the gases given off by powder is taken), it is stated, if 7 ounces of powder were fired in 540 cubic feet of air the proportion of carbon monoxide would not be dangerous, but they give 0.05 of carbon monoxide, and according to Dr. J. S. Haldane this amount is not safe. It is further stated, "if an interval of 5 minutes be allowed to elapse after the firing of the shot before the hewer commences to work, no ill effects would be experienced from the fumes." This statement shows that (540 cubic feet $\times$ 5 or) 2,700 cubic feet are required to purify a working-place after a shot is fired.

Of course, it will be at once seen that if a place has a large quantity of air passing, work may be more speedily resumed after firing the shot, but in any case, after the shot is fired, about 2,500 cubic feet of fresh air are required to make the air in the place as pure as the air was before the shot was fired, and this air sometimes contains 0.11 per cent. of carbon dioxide. It therefore appears that at least 500 cubic feet of air per minute are required for every shot fired to dilute the gases given off by the explosive, depending upon the purity of the air in the first instance.

(VII.) *The Method of Working the Coal.*

The Prussian Commission state that pillar-and-stall work has the advantage that in the process of fore-winning a comparatively large surface of coal-seam is laid bare, and thereby an even continuous evolution of gas is promoted, so that the subsequent operations of coal-working are, as a rule, but little impeded by the presence of fire-damp. On the contrary, in longwall working a full evolution of gas at once occurs from the freshly broken surfaces.

* *Trans. Fed. Inst.*, vol. ii., page 368.

The Austrian Commission refer to the danger of gas coming out of the goaf by reason of barometrical depression, which should be guarded against. All unused roads communicating with the goaf should be closed on the intake and dip side by good stoppings or several feet of stowing, but on the return and rise side they should be left open and a return airway kept to carry off the gas. In longwall working, complete stowage of the goaf is enjoined.

In a case known to the writer, it was found necessary to drive a gas-level to drain off the gas, in the same manner as a water-level drains off water. The particular district was exceedingly gaseous, numerous outbursts of gas had occurred, and various methods were adopted to cope with it: in driving straight-work the gas came off in blowers, which could be felt by the hand at a distance of some 30 inches from the face. The working-faces had to be stopped at intervals for days in order to allow the gas to drain off. When the coal was being worked the outbursts still went on, and bore-holes were put down in the gate-roads, which showed signs of having heaved up (owing to a pressure exerted from beneath). The ventilation had therefore to be specially arranged to prevent the gas from coming into contact with the workmen.

The total quantity of gas that is given off in British coal-mines seems to be far greater than is the case on the Continent. An average of several French collieries gave, in upcast air-currents, 181 cubic feet per minute, or 358 cubic feet per ton of coal produced.*

At Tylorstown colliery, 1.87 per cent. of fire-damp was found in the upcast shaft, with a current of 260,000 cubic feet per minute; this works out to 4,862 cubic feet of gas per minute.†

Messrs. J. B. and W. N. Atkinson‡ estimate that there is $\frac{1}{2}$ per cent. of fire-damp in the air when it reaches the face; it gathers 1 per cent. at the face, making $1\frac{1}{2}$ per cent. when it enters the return airway; and it gathers $\frac{1}{2}$ per cent. in the return airway, making altogether 2 per cent. at the upcast shaft.

It appears, from a perusal of the foreign commissioners' reports, that far more care is taken on the Continent to prevent loss of air through stoppings, overcasts, etc., than is the case in this country. The writer ventures to say that of the total ventilating current in many collieries, particularly the older ones, as much as 10 per cent. is lost in the main-roads, engine-planes, etc., through defective stoppings (about

* *Trans. Fed. Inst.*, vol. x., page 564.

† *Dr. Haldane's Report*, page 27.

‡ *Explosions in Coal Mines*, page 10.

500 cubic feet per minute per 1,000 feet of airway); 15 per cent. is lost on the levels and branch-roads, through stoppings, doors, and overcasts; and 15 per cent. is lost between the levels and the working-face, or 40 per cent. in all. Consequently, in a mine with a total intake air-current of 150,000 cubic feet per minute, only 60 per cent. of this quantity, or 90,000 cubic feet will actually pass the working-face. Members will find it interesting to test these figures by actual measurements in collieries under their charge.

The writer advises that more care should be taken in making the stoppings air-tight—in the first instance, the slits or bolt-holes should be driven as small in every way as possible, and the pillars between the intake and return airways made as thick as possible, a good wall should be built and well plastered, and the slit stowed tight up. In the proposed Coal Mines Act of 1897 it is suggested that overcasts should be made in solid rock. More care should also be taken in erecting doors; walls should be built at each side, at right angles to the door-frame, so as to prevent leakages of air through breaks in the coal.

In order to ascertain the amount of gas given off in a particular district, the ventilating current could be so reduced (when the pit was idle) as to just show a given cap on a safety-lamp, with a given current: say the current was reduced to 5,000 cubic feet per minute, and the lamp indicated 5 per cent. of gas; then there would be 250 cubic feet of gas per minute produced, and to reduce this down to 2 per cent., at which it would be invisible on an ordinary safety-lamp, would require (50 times 250 cubic feet or) 12,500 cubic feet of air per minute.

VIII.—General Conclusions.

The volume of air required for workmen, etc., is as follows:—

	Cubic Feet per Minute.
Each person requires ordinarily when at work	20
Do. when in a working-place giving off $\frac{1}{2}$ per cent. of gas ...	40
Do. with $\frac{2}{3}$ per cent. of gas, to reduce it down to $\frac{1}{2}$ per cent ...	55
Do. „ 1 „ „ „ „ „ „	80
Do. „ $1\frac{1}{2}$ „ „ „ „ „ „	107
Do. „ $1\frac{1}{2}$ „ „ „ „ „ „	115
Do. „ $1\frac{1}{2}$ „ „ „ „ „ „	160
Do. horse requires	90
Do. safety-lamp requires	$0\frac{1}{2}$

It appears that the terms of the General Rules, Nos. 1, 7, 8, and 9 as to gas, may be interpreted as follows:—

General Rule 1.—With safety-lamps.—“Dilute and render harmless,” etc.—

						Percentage Fire-damp.
English Commission, under	...	...	...	...	...	4
Prussian	„	„	...	...	...	4 to 6
French	„	„	...	...	...	4 to 6
Prof. F. Clowes	„	...	...	...	...	5

General Rule 2.—With safety-lamps.—“So diluted as not to be inflammable.” (See General Rule 1.)

General Rule 7.—With safety-lamps.—“Inflammable gas . . . dangerous” :—

						Percentage of Fire-damp.
English Commission	...	...	...	...	...	4½
French	„	safé with	...	...	...	4
Prussian	„	„	...	...	...	4

General Rule 9.—“Safety-lamps—air-current, even if such current be inflammable.” (See General Rule 1.)

General Rule 8.—With naked lights.—“Such quantity of inflammable gas as to render the use of naked lights dangerous” in presence of coal-dust :—

						Percentage of Fire-damp.
English Commission	...	...	...	...	...	2½ to 1½
Prussian	„	„	...	...	...	4
French	„	„	...	...	...	4

It seems desirable that not more than 70 to 100 men and boys should be employed in one split or air-current.

(IX.) Reports and Papers referred to.

Report of the (English) Commissioners on Accidents in Mines, 1886.

The Reports of the Austrian,* Prussian,† and French‡ Fire-damp Commissions.

Explosions in Coal Mines, by Messrs. J. B. and W. N. Atkinson.

Report on the Causes of Death in Colliery Explosions, etc., by Dr. John Haldane.

“An Investigation as to whether the Fumes produced from the Use of Roburite and Tonite in Coal-mines are Injurious to Health,” *Trans. Fed. Inst.*, vol. ii., page 368.

* “The Report of the Austrian Fire-damp Commission,” by Mr. W. N. Atkinson, *Trans. Fed. Inst.*, vol. iii., page 531.

† “Report of the Prussian Fire-damp Commission,” translated by Messrs. P. P. Bedson and L. L. Belinfante, *Trans. Fed. Inst.*, vol. iii., page 1105; vol. iv., page 631; and vol. v., page 500.

‡ *Report of the French Commission on the Use of Explosives in the Presence of Fire-damp*, translated by Messrs. W. J. Bird and M. Walton Brown.

"The Rate of Explosions in Gases," by Prof. H. B. Dixon, *Trans. Fed. Inst.*, vol. iii., page 312.

"Mining Explosives," by Prof. Vivian B. Lewes, *Trans. Fed. Inst.*, vol. ix., page 320.

"The Limiting Explosive Mixtures of Various Combustible Gases with Air," by Prof. F. Clowes, *Trans. Fed. Inst.*, vol. ix., page 373.

"Change of Composition produced in Air by Flames and by Respiration," by Prof. F. Clowes, *Trans. Fed. Inst.*, vol. ix., page 376.

"Investigations on the Composition, Occurrence, and Properties of Black-damp," by Dr. Haldane and Mr. W. N. Atkinson, *Trans. Fed. Inst.*, vol. viii., page 549.

Detection and Estimation of Inflammable Gas and Vapour in the Air, by Prof. F. Clowes.

The writer ventures to hope that he will have done some good to the members of the Institute by drawing attention to the subjects dealt with, but more especially if it only induces them to carefully study the reports and papers referred to. He wishes to acknowledge the valuable assistance rendered to him in the preparation of this paper by Mr. A. A. Atkinson.

The PRESIDENT moved a vote of thanks to Mr. Thirkell for his paper.

Mr. A. M. CHAMBERS seconded the motion, which was agreed to.

MIDLAND INSTITUTE OF MINING, CIVIL, AND
MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,
HELD AT THE HARVEY INSTITUTE, BARNSELEY, JULY 28TH, 1897.

MR. G. BLAKE WALKER, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

Messrs. Thos. Barron and Hy. Nuttall were appointed scrutineers of the ballot-papers for the election of officers and of the ballot-papers for representatives on the council of The Federated Institution of Mining Engineers for 1897-98.

The following gentlemen were elected, having been previously nominated :—

MEMBERS—

Mr. C. C. ELLISON, Mining Engineer, Monckton Main Colliery, Barnsley.
Mr. CLAUDE WILLIAM HILL, Civil Engineer, 8, Guy's Cliffe, Bradford.
Mr. ISAAC HODGES, Mining Engineer and Colliery Manager, Whitwood Collieries, Normanton.
Mr. I. W. H. WHITE, Mining Engineer, Albion Place, Leeds.

ASSOCIATE—

Mr. HENRY JOYNER, Colliery Contractor, Stairfoot, Barnsley.

The Annual Report of the Council and the statement of accounts for the past year were read as follows :—

THE COUNCIL'S ANNUAL REPORT.

The Council have pleasure in presenting to the members of the Institute their report on the work of the past year.

The number of members for the past two years is as follows :—

	1895-96.	1896-97.
Life Members	4	4
Honorary Members...	11	11
Members	223	221
Associate Members ...	10	9
Associates	11	19
Students	9	16
	268	280

Showing a net increase of 12 over last year.

Of the £15 of arrears of subscriptions for 1895-96 and estimated by the auditors to be recoverable, £10 10s. have been collected during the past year, leaving £4 10s., which is now considered irrecoverable. The arrears on June 30th, 1897, amounted to £22 10s., but as the names of these members have not been returned to the secretary of The Federated Institution of Mining Engineers, the arrears are practically *nil*.

The balance at the bank appears somewhat smaller than last year, owing to the rather heavy expenses entailed by the meetings in connexion with The Federated Institution of Mining Engineers, which are in addition to the usual number held, and if allowance be made for these meetings the bank balance would be £63 13s. 3d., as against £50 12s. 4d. last year.

The attention of members is called to the extra cost also entailed on the Institute by the non-payment of subscriptions in due time. Forms for authorizing the respective bankers to pay the subscriptions, can be obtained from the secretary.

The following papers have been read during the past year :—

- “Recovery of Cyanogen and other Residual Products from the Waste Gases of Coke-ovens.” By Mr. Harold Bonser.
- “Electric Coal-cutting on Longwall faces.” By Mr. T. B. A. Clarke.
- “Geology of Deepcar and its surrounding Hills.” By Mr. F. Coultas.
- “The Eastern Extension of the Midland Coal-field, and the Exploration at Southcar.” By Mr. Geo. Dunston.

- "The Use of Electricity at Ackton Hall Colliery." By Messrs. H. St. John Durnford and Roslyn Holiday.
 "The Causes of Death in Colliery Explosions." By Dr. John S. Haldane.
 "Adequate Ventilation and Noxious Gases." By Mr. E. W. Thirkell.
 Presidential Address on "The Education of Mining Engineers." By Mr. Geo. Blake Walker.

The February meeting of The Federated Institution of Mining Engineers was held in Manchester, arrangements for which were made by this Institute, and the following papers were contributed :—

- "Descriptions of Various Types of Ropeways and Remarks as to their Proper Selection." By Mr. W. Carrington.
 "The Detection and Estimation of Carbon Monoxide in the Air by the Flame Cap Test." By Professor Frank Clowes.
 "Determination of Fire-damp in French Collieries." By Mr. J. Coquillion.
 "Railways and their Relation to the Coal Trade." By Mr. Clement Edwards.
 "Appliances for Winding Water." By Mr. W. Galloway.
 "The Cost and Efficiency of Safety-explosives as compared with Gunpowder." By Mr. H. Hall.

Excursions were also made to the *Manchester Courier* and *Evening Mail* offices ; Lancashire and Yorkshire Railway Company's Engineering Works, Horwich ; Messrs. W. H. Bailey & Co., Limited, Albion Works, Salford ; Messrs. Ashton Brothers & Co., Limited, Carrfield Spinning and Weaving Mills, Hyde ; Hyde Lane Colliery Company, Limited, Hyde Colliery, Manchester ; and the Manchester Corporation's Hydraulic Power Station.

During the year a joint meeting has been held with the Chesterfield and Midland Counties Institution of Engineers, at which there was a large attendance of members, and the following papers were read and discussed :—

- "The Enlargement of a Shaft at Lidgett Colliery without Interruption of Coal-winding." By Mr. H. E. Maltby.
 "Electric Haulage at Pleasley Colliery." By Mr. Jonathan Piggford.
 "Recent Progress in the Recovery of Bye-products from Coke-ovens." By Messrs. George Blake Walker and L. T. O'Shea.

A Joint Committee with the Chesterfield and Midland Counties Institution has been formed to consider the order of the Home Secretary with respect to explosives to be used in mines, and more especially to consider the method of testing the explosives to be used to comply with the Act and the kind of apparatus to be erected and its position. This Committee has also presented its report on the apparatus suggested by the Home Office to be erected at Woolwich.

Your Council have taken considerable trouble with respect to the Mining School at Barnsley, and the President (Mr. George Blake Walker) and Dr. Hicks (Principal of Firth College, Sheffield) are members of the committee which is now making arrangements for the continuance of these classes on systematic instruction in mining.

The report of the Mechanical Ventilators Committee has now been completed, but the style in which it shall be issued has not yet been decided upon, owing to one institute which subscribed to the original Committee not being one of the Federated Institutes, and being unwilling to adopt the proposed form of issue.

Your Council would remind the members that it is only by united efforts that the Institute can be carried on successfully, and it behoves each member to try and contribute papers, however short, on any special feature of mining which may come under his notice.

The Council regret that so few students avail themselves of the privileges of membership of the Institute, feeling sure that they could not fail to appreciate the value of the *Transactions*. Members who have students under them would be conferring a great benefit and enlarge the scope of the Institute by endeavouring to induce such students to join the Institute, and the Council propose, at the next Annual Meeting, to suggest a reduction in the subscription of Students to £1 1s. 0d. per annum, the limit of age to be 28 years.

DR. THE TREASURER (Mr. T. W. H. MITCHELL) IN ACCOUNT
MECHANICAL

July 1st, 1896.	£	s.	d.	£	s.	d.
To Balance at Bankers	50	12	4			
„ Cash in Treasurer's hands	9	0	0			
				59	12	4
June 30th, 1897.						
To Subscriptions for 1896-97	384	0	0			
„ „ paid in advance for 1897-98	4	10	0			
„ Arrears	10	10	0			
				399	0	0
„ Sale of Dinner Tickets	13	9	6			
„ Members' portion of the Wine Account at the Annual Dinner	3	0	0			
				16	9	6
„ The Federated Institution of Mining Engineers— Manchester Meeting—Sale of Dinner Tickets	17	15	0			
„ Members' portion of the Wine Account	6	9	11			
				24	4	11
„ The Federated Institution of Mining Engineers— Students' Meeting—Sale of Dinner Tickets				1	11	6
„ Sales of <i>Transactions</i> and Authors' Copies of Papers				5	6	0
„ Letting of Room				0	12	6
„ Bank Interest				3	17	5
„ Chesterfield and Midland Counties Institution of Engineers—Moiety of Expenses of Joint Meeting				2	14	5

Audited and found correct,

E. W. THIRKELL,

AUDITOR.

August 16th, 1897.

£513 8 7

WITH THE MIDLAND INSTITUTE OF MINING, CIVIL, AND
ENGINEERS, 1896-97.

CR.

June 30th, 1897.	£	s.	d.	£	s.	d.
By The Federated Institution of Mining Engineers:—						
Call of 17s. per Member on 265 Members for						
1896-97	225	5	0			
„ Balance of Call for 1895-96	0	17	0			
„ Excerpt <i>Transactions</i> , etc.	13	3	5			
„ Reducing Plates	0	10	0			
„ Proportion of cost of Exchanging <i>Transactions</i>						
with other Societies	0	3	4	239	18	9
„ Expenses in connexion with the Manchester Meeting of The						
Federated Institution of Mining Engineers				43	8	7
„ Expenses in connexion with the Students' Meeting of The						
Federated Institution of Mining Engineers				5	5	6
„ Annual Dinner				21	11	6
„ Printing and Stationery				18	18	3
„ Office Rent				12	0	0
„ Reporter				13	10	0
„ Insurance				1	11	6
„ Cleaning				0	13	0
„ Gas Company				0	5	7
„ Hire of Rooms for Meetings at Leeds, Sheffield, Wakefield,						
and Barnsley				3	15	0
„ Secretary's Salary	£50	0	0			
„ „ Expenses	11	11	7			
				61	11	7
„ Joiner-work				1	15	8
„ Preparation of Catalogue				10	0	0
„ North of England Institute of Mining and Mechanical En-						
gineers—Proportion of Fan Committee's Expenses				16	0	4
„ Stamps, Telegrams, Carriage, Wrappers, and Sundries				18	3	8
„ Balance at Bankers	£40	15	8			
„ Cash in Treasurer's hands	4	4	0			
				44	19	8

£513 8 7

MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.
GENERAL STATEMENT, 1896-97.

LIABILITIES.		ASSETS.	
1897.	£ s. d.	1897.	£ s. d.
June 30.—None.		June 30.—By Cash in Bank ...	40 15 8
Balance, being capital ...	432 7 4	" " Treasurer's hands ...	4 4 0
			44 19 8
		" Instruments for Fan Experi- ments, one-third portion ...	34 6 8
		" Value of 6,778 parts of <i>Transactions</i> , at 1s. ...	388 18 0
		" Value of 116 Copies of Narra- tives of Sudden Outbursts of Gas, at 1s. ...	5 16 0
		" Value of 119 Copies of Com- mittee's Report on Safety- lamps, at 1s. ...	5 19 0
		" Value of 16 Copies of Report of French Commission on Use of Explosives, at 3s. ...	2 8 0
			387 7 8
		" Arrears of Subscriptions ...	nil
	432 7 4		432 7 4

August 16th, 1897.

Audited and found correct,
E. W. THIRKELL, AUDITOR.

The PRESIDENT, in moving the adoption of the report and statement of accounts, said that it was desirable that mining students should be interested in, and have the opportunity of availing themselves of the advantages of the Institute.

Mr. JOHN NEVIN seconded the motion, which was carried.

ALTERATION OF RULES.

The PRESIDENT gave notice that, at the next Annual Meeting, he would move "that the Students' fee be £1 1s. in future, instead of £1 10s. as now; and that the age limit for Students be the same as in the North of England Institute of Mining and Mechanical Engineers, viz., 23 years."

ELECTION OF OFFICERS FOR 1897-98.

The scrutineers reported the results of the elections as follows :—

PRESIDENT :

Mr. GEORGE BLAKE WALKER.

VICE-PRESIDENTS :

Mr. E. W. THIRKELL. | Mr. F. N. WARDELL. | Mr. J. R. ROBINSON WILSON.

COUNCIL :

Mr. J. E. CHAMBERS.

Mr. J. L. MARSHALL.

Mr. H. ST. JOHN DURNFORD.

Mr. J. MELLORS.

Mr. JNO. LONGBOTHAM.

Mr. H. B. NASH.

Mr. M. HALL.

Mr. R. TURNBULL.

SECRETARY AND TREASURER :

Mr. T. W. H. MITCHELL.

REPRESENTATIVES ON THE COUNCIL OF THE FEDERATED INSTITUTION OF MINING ENGINEERS, 1897-98.

Mr. A. M. CHAMBERS.

Mr. C. E. RHODES.

Mr. W. E. GARFORTH.

Mr. E. W. THIRKELL.

Mr. J. LONGBOTHAM.

Mr. G. B. WALKER.

Mr. H. B. NASH.

Mr. F. N. WARDELL.

Mr. JNO. NEVIN.

The following paper on the "Transvaal Coal-fields," by Mr. Rowland Gascoyne, was read :—

TRANSVAAL COAL-FIELDS.

By ROWLAND GASCOYNE.

INTRODUCTION.

So much has been written and said lately about the Transvaal that the writer hopes by bringing to the attention of the members a few notes on the principal coal-fields of the South African Republic some interest will be aroused in the development of such an interesting country, especially as the conditions under which the work is carried on are so different to those prevailing at home.

The Transvaal or South African Republic lies between latitude 22° and 28° south. The scenery in the coal-bearing districts cannot be said to be of an attractive character, but it will be gathered from what is hereafter said that the country offers every inducement to Europeans to settle therein.

Physical Features.—What strikes a stranger on visiting the Transvaal is the monotonous, undulating character of the country, its total absence of trees, especially amongst the southern and principal coal-fields, which to a geologist appear to have been deposited originally in valleys existing amongst older rocks, so that their occurrence has tended towards levelling up as it were the surface appearance of the country, and thus intensified the monotony of the scenery. These plains, however, lie something like 6,000 feet above the level of the sea, and in the summer time (November to March) are covered with vegetation, wide but shallow streams being frequently met with, whilst large sheets of water sometimes several miles in circumference are to be seen in the larger depressions which appear to have been formed along lines of disturbance. The present form of these small valleys is therefore due to the denudation which of course would be more easily formed along the lines of these disturbances. On the older rocks these depressions or "pans" are generally more circular in shape, and are said generally to denote troubled ground. In the winter when there is no rainfall the pans become dry, the streams more or less disappear, and the surface of the ground presents generally a parched appearance, and what was in summer a mass of green country interspersed with flowers now becomes nothing but a mass of dry and withered grass.

Climate.—Owing to the fact that the country lies some 6,000 feet above sea-level, notwithstanding its latitude, the Transvaal possesses a beautiful climate. In summer there are frequent thunderstorms, but the rain clouds act as a shield to the rays of the sun, whilst in winter there is a cloudless blue sky without rain, and the nights are only sufficiently cool to be pleasant.

Geology.—With regard to the actual geological age of the coal-bearing beds of the Transvaal, there appears to be considerable diversity of opinion, and the attempts hitherto made to fix their position in the European geological formations have not been attended with any marked success. In fact, there is a difference of opinion in this respect with regard to the geological structure of the Transvaal generally. But as the country becomes developed, increased light is being thrown on to the geological age and sequence of the different beds and formations, especially by the discovery of characteristic fossils, which are, unfortunately, very rare in the Transvaal.

The coal-bearing beds of the Transvaal consist of coarse, siliceous sandstones, with beds of shale and local beds of coal. These coal-bearing beds, as a rule, have only a slight dip, and in many cases are practically level; they are liable to rapid variations in thickness in short distances, especially in the case of coal-seams, which vary rapidly in thickness, in quality, and in appearance. In all cases where the base is seen, the Coal-measures rest unconformably upon the older measures, generally quartzites, or even older rocks, dipping at high angles. Very frequently the Coal-measures rest on an irregular deposit of quartzite rock, *débris*, or breccia, evidently formed by denudation of the underlying rocks, and showing that a considerable time elapsed after the tilting of the older rocks before the deposition of the coal-bearing beds.

Another interesting fact is that the coal-seams are not continuous over any extensive area, not even in what is regarded as the same coal-field. It would appear from the general indications surrounding these deposits that the coal-seams were originally laid down in separate patches and not continuous, as was the case with most of the European deposits, notwithstanding the fact that there is a general geological sequence throughout the whole of the fields hitherto discovered.

The writer agrees with the opinion formed by Mr. W. Forster Brown that the whole of the Transvaal coal-fields are contemporaneous, and that the seams worked at some of the different collieries are identical in age, notwithstanding the intervention of barren country between.

The principal series of coal-deposits may be said to extend from Standerton on the south to Middelburg on the north, a distance of about 200 miles; and from Ermelo on the east to Balmoral on the west, a distance of about 100 miles. There are also outside this area other detached coal-fields, such as those at Springs, Boxburg, Heidelberg, on the Vaal river, and on the borders of Zululand, whilst the writer has also seen similar deposits about 50 miles north of Johannesburg and also considerably to the north of Nylstroom in the Waterburg district. These coal-deposits, although occurring in isolated patches, are consequently found more or less nearly all over the Transvaal.

With regard to the classification and arrangement of the South African geological formations, no one has done more than the late Prof. Green, whose work is to be seen in the interesting papers on geological subjects printed in the *Transactions* of this Institute. Most writers on South African geology, adopt the late Prof. Green's classification of the formations found in Cape Colony, and which in descending order are as follow* :—

Alluvial.
 Cretaceous.
 Stormberg Beds.
 Volcanic Beds.
 Cave Sandstone.
 Red Beds.
 Molteno Beds.
 Karoo Beds.
 Kimberley Shales.
 (Unconformity.)
 Ecca Beds.
 Dwyka Conglomerates.
 (Unconformity.)
 Quartzites.
 Bokkeveld Beds.
 Table Mountain Sandstone.
 Slates and Intrusive Granite.
 Malmesbury Beds.

In the Transvaal, sufficient is not yet known of its geology to identify satisfactorily the above sub-divisions or the European geological

* "Correlation of Strata in South Africa." By Mr. Walcot Gibson. *Trans. Fed. Inst.*, vol. xii., page 319.

formations. Most of the sub-divisions, not yet recognized in the Transvaal, have been found in the neighbouring states and no doubt as mining operations are extended in the coal-bearing measures the other sub-divisions will become known and recognized.

So far the precise geological age of the coal-bearing rocks has not been definitely settled, but from general appearances, and the fact that the writer has found fossils which appear to be *Glossopteris*, he is inclined to consider them of Triassic age, although there are other writers who seem equally convinced that they belong to the Oolite, Permian, or Carboniferous period. Some writers consider that the coal-seams occur in the Cave Sandstone divisions, but the writer thinks with many others that at all events as far as explorations have gone at present, the Transvaal coal-seams ought to be placed in the Molteno Beds. It may be that coal-seams exist in other beds, but the coarse grey grits of the Molteno group are so conspicuous immediately above the thick coal-seam and cover such an extensive area as to leave little room for doubt as to which division the coal-seams ought to be placed.

It appears to the writer that Triassic beds have not been so well developed in the Transvaal as in Cape Colony as far as thickness and variety are concerned, but they are infinitely richer in coal-seams both in number, thickness, and quality. The marked break or unconformity that exists between the older measures and the coal-bearing rocks in most instances undoubtedly shows an interval of a considerable lapse of time, whilst the comparative flatness and freedom from disturbing influences of the Coal-measures as compared with the older quartzites also points to a more settled time and existence of quite different conditions.

It is difficult to speak with certainty as to the exact conditions under which the coal-seams were deposited, and although there are many points to be observed in favour of the drift theory, there are authorities who think there are as many points to be urged against it. The writer has already pointed out that there are indications of the coal-seams having been laid down in different patches and it is interesting to notice that in the outside fringes of the detached coal-fields, the seam of coal thins out as though approaching an old land surface, whilst the different isolated coal-fields, by the intervention of barren ground, although only a few hundred feet in width often show remarkable difference in the structure, quality, and thickness of the coal-seams.

The writer is of opinion that there is much to be said of the view put forward by Mr. W. Forster Brown, in his paper on "The Transvaal Coal-field," printed in the *Transactions* of the South Wales Institute of

Engineers,* in which it is stated that the coal-seams probably grew in large morasses. This theory appears to the writer to best fit in with all the surrounding circumstances; and to account for the existence of such thick seams as are to be found in the Transvaal, it is also necessary to assume that the climatic conditions favoured a rapid growth of vegetation. For the information of those who take an interest in the different theories as to the formation of coal-seams, it may be mentioned that in the Transvaal, the coal-seams generally have a shale floor and not unfrequently a sandstone floor: a fire-clay floor being the exception and not the rule as is the case in European coal-fields. It not unfrequently happens that the sandstones of the Coal-measures are to be found well developed and resting directly on the older rocks without the intervention of coal-seams; whilst instances are known of mines being opened to work isolated deposits, in appearance like dull cannel coal, and of so earthy a nature that it is difficult to decide whether to describe them as shale or coal-mines. In small local deposits of this kind, the specific gravity is high and the ash of a deep red colour, whilst in the larger deposits the ash is not unfrequently white in colour. In the sandstones overlying the coal-seams, fossil shells of *glossopteris* have been found whilst in the coal-seams and shales *pecopteris* and *neuropteris* are found in a fragmentary condition; stems of trees somewhat like *lepidodendron* are found in the sandstones, but like all vegetable remains occurring in sandstones they are not found in a good state of preservation.

DESCRIPTION OF COAL-FIELDS.

Vaal River.—Near Vereeniging, on the Vaal river, coal has been extensively worked by Messrs. Lewis & Marks for several years past. This coal-field forms part of a much larger coal-field extending in a southerly direction into the Orange Free State. The section of strata proved is as follows:—

No.	Description of Strata.	Thickness of Strata.		Depth from Surface.	
		Ft.	In.	Ft.	In.
1	Loam	15	0	15	0
2	Clay	48	0	63	0
3	COAL, shaly	8	0	71	0
4	Yellow sandstone	10	0	81	0
5	COAL, good	8	0	89	0
6	Black shale	10	0	99	0
7	Clay	36	0	135	0
8	Quartzite	—	—	—	—

* Vol. xx., page 134.

When the writer visited this colliery, the system of working adopted was pillar-and-stall, the stalls being 12 feet wide, 75 feet long, centre to centre, leaving pillars of solid coal 60 feet by 60 feet, to be worked out subsequently. The coal is of comparatively good quality and may be used for steam, house, and smiths' purposes; it is largely used on the Cape Government railways for steam, and in Johannesburg for house and smiths' purposes. The bottom bed of clay makes a fair fire-brick, which is largely used for boiler-flues and other purposes at the Transvaal gold-mines.

Heidelberg.—The next coal-field calling for attention is situated near Heidelberg, and generally known by the name of the Heidelberg coal-field. Like all the other Transvaal coal-fields it occurs in detached fields, and recent explorations by aid of the diamond drill have shown it to extend much farther in a southerly direction than was at one time anticipated. The coal-seams vary in thickness from 4 feet to 25 feet, the last-named, however, having frequently small intervening bands of shale, although in one instance the seam is over 20 feet thick and free from shale bands. As in the case of the Vaal River coal-field, two distinct seams of coal have been proved, but they vary in thickness and quality within comparatively small distances. It is said that some of the bore-holes have proved three or four distinct seams of coal in a less depth than 400 feet. The coal is superior to that of Vaal River for smith and gas purposes, the best analyses running as under:—Carbon, 70 to 75 per cent.; ash, 10 to 20; volatile matter, 18 to 20; sulphur, 0·90 to 1·20; and moisture, 5 to 10 per cent.

The collieries at present working only produce a small output, and until they are connected with the Natal railway, which passes a few miles north of the coal-field, there is not much prospect of the collieries being developed to any extent.

Boksburg.—The next coal-field is that of Boksburg, alongside the Springs and Johannesburg railway, and of small extent. The seam of coal varies in thickness from 10 feet to 18 feet. In appearance it is similar to cannel, but slightly duller, with a high percentage of ash, the average being about 20 per cent. The coal is worked by several small collieries, and the depth being only about 50 feet, no expensive plant is needed. There is a ready demand for the output at the neighbouring gold-mines for steam purposes. This coal-field, with its six collieries, when at its best never produced much more than 100,000 tons per year.

The system of working adopted is that of pillar-and-stall, the regulation size of the pillars being 8 feet square and stalls 10 feet wide; but it not unfrequently happens, when there is an urgent demand for coal, that the pillars are reduced and the stalls increased in size, with the result that the ground falls in to the surface.

Springs.—About 6 miles further to the east of Boksburg is found the principal coal-field from which the gold-mines have hitherto drawn their supplies of steam coal, and upon which the Brakpan, Springs, Cassel, and Great Eastern collieries are situated. The extent of this coal-field has not been fully proved, but, taking Springs colliery as the centre, coal has been proved to exist on all sides; and in both northerly and easterly directions detached coal-fields have been proved for many miles. Although the coal about Springs cannot be said to be of very good quality it is much better than the Boksburg coal, and it compares very favourably with the Brakpan coal, and being a fairly good steam coal and close to the gold-mines it is probable that it will always have a marked advantage over the other coal-fields. The strata does not show any material alteration to that already described, the following being the section as proved at the Brakpan collieries:—

No.	Description of Strata.	Thickness of Strata.		Depth from Surface.	
		Ft.	In.	Ft.	In.
1	Surface soil	16	0	16	0
2	Clay	6	0	22	0
3	Pot-clay	17	0	39	0
4	Sandstone	10	0	49	0
5	Sandy clay	9	6	58	6
6	Sandstone	21	6	80	0
7	Shale	5	0	85	0
8	COAL, good	2	8	87	8
9	Black shale	9	0	96	8
10	COAL	21	0	117	8
11	Shale	3	6	121	2
12	Sandstone	2	0	123	2
13	Conglomerate	3	6	126	8
14	Quartzite	3	4	130	0

The seam of coal, 21 feet thick, varies in thickness from 18 feet to 22 feet in different parts of the field, the better portion being always found in the bottom 6 feet or 8 feet, and gradually as we ascend the seam becomes less pure and more intermixed with shale. The more closely the coal approaches that of shale in appearance, or, in other words, the duller it becomes it contains more ash, and the heating power is diminished. In the same colliery, within 1,000 feet, the character of the

coal frequently changes completely, thus the old main shaft and the new main shaft, at Brakpan, produce entirely different classes of coal although on the same property and close to each other. The same thing happens further east, the coal at Springs being of a different character to that produced at the Cassel and Great Eastern collieries. The following sections of strata, about the centre of the above collieries, show how beds of shale alternate with seams of coal:—

CASSEL COLLIERY.

No.	Description of Strata.	Thickness of Strata.			Depth from Surface.	
		Ft.	In.		Ft.	In.
1	Clay, sandstone, and shale ...	93	0	...	93	0
2	COAL, good and bright ...	5	0	...	98	0
3	Shale	14	0	...	112	0
4	COAL	18	0	...	130	0
5	Shale	6	0	...	136	0
6	COAL	22	0	...	158	0
7	Shale	16	0	...	174	0

GREAT EASTERN COLLIERY, PROSPECTING SHAFT.

No.	Description of Strata.	Thickness of Strata.			Depth from Surface.	
		Ft.	In.		Ft.	In.
1	Soil	3	0	...	3	0
2	Clay, sandstone, and shale ...	95	6	...	98	6
3	COAL, bright and good ..	2	0	...	100	6
4	Shale	8	0	...	108	6
5	COAL	2	0	...	110	6
6	Shale	4	0	...	114	6
7	Breccia	0	9	...	115	3
8	Shale	10	7	...	125	10
9	COAL	5	0	...	130	10
10	Shale	0	6	...	131	4
11	COAL	6	0	...	137	4
12	Shale	4	6	...	141	10
13	COAL	4	7	...	146	5
14	COAL and shale	6	6	...	152	11
15	COAL	2	0	...	154	11
16	Shale	0	2	...	155	1
17	COAL	6	1	...	161	2
18	COAL	5	4	...	166	6
19	Shale	10	0	...	176	0
20	Quartzite	—	—	...	—	—

It should be noted, however, that the Cassel and Great Eastern properties contain well developed seams of coal comparatively free from shale partings, but they are nevertheless liable to variations in thickness.

Witklip.—Travelling in an easterly direction, there are various farms, where seams of coal have been proved, in fact isolated coal-fields may be expected to be found more or less all the way to Middelburg. Large

tracts of intervening country occupied by the older rocks will occur here and there, but very little prospecting suffices to show the geological age of the rocks when no other indications can be found. On the Witklip farm, about 12 miles east of Springs, a borehole was put down to a depth of 76 feet, the bore penetrating a seam at a depth of 61 feet and was still in the coal when stopped, thus proving the seam to be over 15 feet thick. This coal has a dull lustre like Brakpan coal, and an analyses of two samples gave the following results:—

	I.	II.
Carbon	66·00	57·00
Volatile matter ...	10·45	17·60
Ash	13·00	16·50
Moisture	10·55	8·90
Specific gravity ...	1·62	1·78

This coal is a fair steam coal, but not sufficiently good to bear the carriage by ox-waggons to Springs station in competition with existing collieries.

Wilge River.—The next coal-field upon which any work has been done is 20 miles further eastward on the Wilge river, where mines were opened to supply the gold-mines before the Boksburg and Brakpan deposits were discovered. The coal outcrops on the river bank and shows the following section:—

No.	Description of Strata.	Thickness of Strata.		Depth from Surface.
		Ft.	In.	
1	Sandstone	10	0	10 0
2	COAL	0	4	10 4
3	Sandstone	0	3	10 7
4	COAL	0	6	11 1
5	Shale	0	6	11 7
6	COAL, bright	1	2	12 9
7	Shale	1	0	13 9
8	COAL, bright	1	7	15 4
9	Shale	0	6	15 10
10	COAL	2	0	17 10
11	Shale	0	2	18 0
12	COAL, steam	17	0	35 0

The two seams of coal of 1 foot 2 inches and 1 foot 7 inches in thickness, with a shale parting between, are bright coals suitable for smithy and gas purposes, and give the following results on analysis:—

Carbon	56·15
Volatile matter ...	34·24
Moisture	6·10
Ash	3·05
Sulphur	0·46
Specific gravity ...	1·30

Owing to the scarcity of this class of coal and high cost of transport, this coal has been readily sold in Johannesburg at from £4 to £5 a ton. The thick seam being inferior and similar in quality to that worked in the collieries in the neighbourhood of Springs and Brakpan is unworkable at a profit owing to the want of railway accommodation. There can be little doubt but that these seams are contemporaneous with the seams of coal found at Springs, Brakpan, and Boksburg, the thin seam of bright good coal in all cases overlying the thick dull seam of steam coal, whilst still further to the east the same geological sequence in the seams of coal may be observed.

Steam Coal Spruit.—About 30 miles to the north-east, in what is known as the Steam Coal Spruit coal-field, the better class of coal was worked for smithy purposes of the following section :—

No.	Description of Strata.	Thickness of Strata.		Depth from Surface.	
		Ft.	In.	Ft.	In.
1	Soil	6	0	6	0
2	Fine-grained sandstone ...	10	0	16	0
3	Black shale	4	0	20	0
4	COAL, good	1	0	21	0
5	Blue shale	2	0	23	0
6	COAL	2	6	25	6
7	Black shale	—	—	—	—

When these mines were working the coal commanded £4 per ton and upwards in Johannesburg, but of this price the transport cost over £3 per ton, leaving about 15s. per ton net at the mines.

Olifants River.—Still further north is the Olifants river coal-field possessing probably the best coal yet found in the Transvaal, but owing to lack of railway accommodation it cannot be worked to advantage. The section of strata shown in the shaft of the Rand Coal Mining Company's mine at Van Dykes Drift was as under :—

No.	Description of Strata.	Thickness of Strata.		Depth from Surface.	
		Ft.	In.	Ft.	In.
1	Soil and clay	15	0	15	0
2	Sandstone	23	0	38	0
3	COAL	0	9	38	9
4	Shale	2	6	41	3
5	COAL	1	0	42	3
6	Sandstone	13	0	55	3
7	Grey fine-grained sandstone...	18	0	73	3
8	Shale	10	0	83	3
9	COAL, bright	5	0	88	3
10	COAL, dull steam	9	6	97	9
11	Black shale	—	—	—	—

The 5 feet of bright coal was the only portion of the seam worked, and this owing to the difficulties of transport only to a small extent. This coal produced a good coke which commanded a high price in Johannesburg, £10 to £13 a ton being paid for it for assaying purposes.

Ermelo.—Further south, in the neighbourhood of Ermelo, seams of coal both bright and dull are found, varying from 2 feet to 6 feet in thickness, but in the absence of railway facilities and local markets the prospects of these coal-fields being opened up are somewhat remote.

Middelburg, Balmoral, etc.—West of Middelburg, alongside the Pretoria and Delagoa Bay railway, especially in the neighbourhood of Balmoral, several important collieries are being opened up. Probably the most important is the Douglas colliery, close to Balmoral station, some 45 miles distant from Pretoria, and connected with the Pretoria and Delagoa Bay railway by a branch line about 2 miles long. Douglas colliery has been working some time, and the section of the strata is as follows :—

No.	Description of Strata.	Thickness of Strata.			Depth of Strata.	
		Ft.	In.		Ft.	In.
1	Soil	3	0	...	3	0
2	Coarse sandstones and shales	40	0	...	43	0
3	COAL, dull steam	6	0	...	49	0
4	COAL, bright smithy	4	6	...	53	6
5	COAL, smithy and steam, mixed	3	9	...	57	3
6	COAL, bright gas and coking	4	9	...	62	0
7	Sandstone, hard and coarse ...	4	0	...	66	0
8	COAL, bright smithy	4	6	...	70	6
9	COAL, inferior	0	6	...	71	0
10	Black shale	—		...	—	

It will be noticed that there are two seams of marketable coal, the upper one 19 feet thick, and the lower one 4 feet 6 inches, making in all 23 feet 6 inches of coal. The upper seam is very valuable, as it contains all the different qualities of coal likely to be required, such as steam, house, smithy, gas, and coking, the better qualities containing only from 5 to 6 per cent. of ash.

Nearer Middelburg, and some few miles further along the Pretoria and Delagoa Bay railway, at the Silksworth colliery, the following section is given :—

No.	Description of Strata.	Thickness of Strata.			Depth from Surface.	
		Ft.	In.		Ft.	In.
1	Blue shale	16	0	...	16	0
2	COAL, steam	5	0	...	21	0
3	COAL, smithy and steam, mixed	3	0	...	24	0
4	Shale	1	0	...	25	0
5	COAL, bright smithy ...	2	6	...	27	6
6	COAL, seconds smithy ...	10	6	...	38	0

Between Silksworth colliery and Middelburg, more or less distant from the railway, mining operations on a limited scale are being carried on; and on the other side of Middelburg, near Belfast, several seams of coal are being opened up, from 4 feet to 10 feet in thickness. As these deposits are more or less the same in character as those already described, further detailed descriptions are unnecessary.

Honignest Krantz, etc.—Perhaps the most important discovery of coal recently made is that at Honignest Krantz, about 10 miles north of Pretoria, on one of the patches of Coal-measures previously described, prospecting operations having shown the existence of no less than three seams of coal, varying in thickness from 3 to 10 feet, and suitable for both steam, smithy, and gas purposes. As the mines are on the Pretoria and Pietersburg line of railway and less than 50 miles from the Rand, there is every prospect of successful colliery operations being carried on.

Less than 1 mile north of the hotel at Hammons Kraal, on the road from Pretoria to Nylstroom, and likewise near Pineaars river on the same road, the writer has observed deposits of Coal-measures, and no doubt several coal-fields exist in this neighbourhood, so that on the conclusion of the Pietersburg line of railway there is every prospect of these coal-deposits being extensively and profitably worked.

METHODS OF WORKING.

Owing to most of the seams of coal being thick and situated near to the surface, the system of working in vogue is principally pillar-and-stall, but the system varies considerably in different parts of the country as to the dimension of the pillars and the stalls. At Messrs. Lewis & Marks Vereeniging collieries, where the ground is somewhat soft and the surface intersected by the Vaal river, which in summer time is liable to flood the surrounding country, the stalls are only 12 feet wide, whilst the pillars are left 60 feet square: a wise and prudent system under the circumstances.

On the other hand, in the small collieries at Boksburg, the working of the coal is carried on with but little regard as to whether the surface is broken or not. Stalls 10 feet wide, and pillars 8 feet square, are quite ample to keep the ground intact, but frequently the pillars are so reduced and so little regard paid to safety that the burning waste heap is so honeycombed by the underground workings at times as to find its way into the mine by the collapse of the surface and give rise to endless trouble, and in some instances cause the stoppage of the mine. In working such a thick seam as that at Boksburg, the lower 6 feet or 8 feet are extracted first, and then another lift, 3 or 4 feet thick, as the demand for coal requires or thickness of seam admits.

At the Brakpan collieries, where the seam is 22 feet thick and 80 to 100 feet deep to the top of the seam, various systems of working have been tried, even longwall on a limited scale, which, considering the nature of the strata and the fact that 15 feet of coal were extracted from the seam, soon caused the ground to fall to the surface; an occurrence which likewise frequently happened when the pillars were reduced to 4 or 5 feet square, but this reduction of pillars was principally carried on where a fall to the surface would be of little consequence and when there was an extraordinary demand for coal. The fixed rule with regard to working pillar-and-stall adopted was first to block out the seam into squares of 90 feet on the side, the development roads being driven 9 feet wide and 8 feet high. From these roads, stalls are driven of a maximum width of 15 feet, leaving pillars from 10 to 12 feet thick. In the first working, 8 feet of the seam was extracted, the other 6 or 7 feet being sometimes taken down and sometimes left as a reserve, because being easier to work it was found useful when there was an extra demand for coal or great scarcity of Kaffir labour. A much better system and one that yielded more coal at less expense was to confine the preliminary or development roads to those absolutely necessary for tramming purposes, say every 300 feet at the least, and to attack the coal with 15 feet openings, leaving pillars 12 feet square to carry the roof. Under this system of working, the Kaffirs had frequently a working-face of 30 feet; the result being a greater yield of large and better coal (the bottom portion of the seam being the best), whilst if any extra support was required at any time it could be left in the shape of inferior roof-coal between the pillars. Under this method, ample support was left and when the top coal was taken down, the coal left was in the shape of an arch supported by the square pillars so that a fall was not possible. The coal being hard with a total absence of cleats or slines, the explosive used

was dynamite, and the wider the working-face the better and more effective was the work done by the dynamite. Dynamite was dear, and there being absolutely no sale for small-coal (less than nuts), all small-coal produced was a dead loss.

In the Steam Coal Spruit and Olifants river districts, where the seams are thinner, the longwall system of working was introduced with considerable success, but owing to the lack of railway accommodation work was only carried on on a limited scale.

The tramming underground is generally performed by Kaffirs.

In all the districts, except Middelburg, shafts both circular and rectangular are in use. In that district, the coal is generally won by adits. The winding engines are mostly worked on the second motion, the shafts being too shallow for direct-acting winding-engines to be employed successfully.

All the large collieries are well-fitted up with screens and picking belts, although only two classes, coal and nuts, are made.

Labour.—The bulk of the labour is performed by Kaffirs under the supervision of Europeans. The Kaffirs work both by day and by contract, the latter being by far the most satisfactory system. By day, the Kaffir is paid on an average about 2s., the company housing and feeding him at a further cost of about 6d. a day. In time, the Kaffir becomes fairly proficient at his work, and the longer he stays the more proficient he becomes. For work requiring skill and intelligence he is unsuited, and for winding, stoking, and similar work European labour is necessary. Generally speaking, at the collieries working the thick seams, one European can supervise fifty boys or Kaffirs, and if the underground operations are carried on under a proper system, there is no difficulty in obtaining an average output of one ton of saleable coal per day per Kaffir employed. Europeans earn on an average about £1 per day as overseers, carpenters, fitters, blacksmiths, enginemen, etc., with free rooms and coal in addition.

Cost of Working.—The cost of working varies a good deal in the various districts, according to local conditions, method of working adopted, etc., the cost of course being highest during the time the mine is being opened out, when the output is small with a large amount of narrow work on hand. In the thick seam at Brakpan, Boksburg, and Springs, with the collieries properly developed and plenty of demand for the coal, the cost should run about 4s. 6d. per ton put into trucks at the mines.

The cost at Brakpan colliery on an output of 21,000 tons for the month coming out as follows :—

Kaffir labour	...	...	...	...	s.	d.
White labour	...	...	...	...	0	10
Stores, etc.	...	...	...	...	1	0
Feeding natives and other charges	...	...	...	...	0	8
Total cost...	...	...	...	..	4	6

With an output of 16,000 tons per month, the cost, however, reached 5s. per ton. In the mines with thinner seams the cost is as high as 6s to 8s. per ton, especially where the coal is obtained from narrow bords.

Quality of the Coal.—As previously described, the quality of the coal is very variable, the same seam varying considerably within a comparatively short distance. It may be said that the Transvaal coals are suited for almost every purpose, but generally they are classed as steam, smithy, and gas coals. The best coal for all purposes undoubtedly is that found in the Middelburg district, but its distance from the chief markets will only permit of its being worked to a very limited extent. The best coal yet found near Middelburg by the writer had the following analysis :—

					Per Cent.
Carbon	...	...	...	...	67·43
Volatile matter	...	...	...	...	31·09
Sulphur	...	...	...	...	0·42
Ash	...	...	...	...	1·06

There is also an abundance of coal containing from 5 per cent. to 10 per cent. of ash, and in seams from 5 feet to 10 feet in thickness. Next after the Middelburg coals come those of Heidelberg, with 10 per cent. of ash, and following these in order are the Vaal river, Brakpan, and Boksburg coals, the two latter containing from 10 per cent. to 20 per cent. of ash. All the coals, except those of the Middelburg district, are more suited for steam purposes than anything else, but unfortunately the demand for coal outside steam purposes is, in the Transvaal, of a very limited character. The consumption for household purposes is principally confined to cooking stoves, for which any ordinary coal will suffice.

Railways and Markets.—It may be taken for granted that without railways very few markets can be found for the output from the collieries, and as the Witwatersrand gold-mines form the principal market, collieries to supply that market must be able to compete with the cheaply-worked mines at Boksburg, Brakpan, and Springs, from which, hitherto, the gold-mines and the Rand trams have drawn the bulk of their supply. The Vaal river collieries dispose of the bulk of their out-

put to the Cape Government railways, and no doubt when the Heidelberg collieries are connected with the Natal and South African Railway they will be able to find a better outlet for their coal. It would seem that, despite the very ordinary quality of the coal from the Boksburg and Springs mines, its cheapness will always secure it a sale at the gold-mines. Some of the collieries near Balmoral, on the Pretoria and Delagoa Bay railway, especially the Douglas colliery, ought likewise to command a fair trade at the gold-mines. It is to be hoped that the collieries round Middelburg will be able to find an outlet at Delagoa Bay, about which there is considerable doubt, or they will probably have to wait many years before the country becomes sufficiently developed to consume the output of the different collieries now being opened up in that district.

There is no sale for small coal (about 20 per cent. passing through a gauze of $\frac{3}{4}$ inch mesh). The actual production at the thick seam collieries, worked on the pillar-and-stall system, is: large coal, 60 per cent.; nut coal, 20 per cent.; and small coal, 20 per cent. Four years ago large coal sold for 12s. per ton and nuts for 8s. per ton at the pits, but to-day they sell for 10s. and 7s. per ton respectively. At the other mines the prices are about the same, the difference in quality for which higher prices are paid being swallowed up by the heavier railway rate.

The Rand gold-mines will continue to form the principal centre of consumption, and as this industry continues to thrive a better demand for coal will likewise arise. The principal want felt by the collieries is improved transport, in the shape of railway accommodation, the demand for coal having increased by such leaps and bounds as to severely overtax the accommodation provided by the Netherlands Railway Company. The bagging of the whole of the output is likewise a considerable source of trouble and expense; but steps are being taken to overcome this difficulty.

The resources of the Transvaal coal-fields are, no doubt, ample for many years to come, but as the coal-seams are patchy in character, it may happen that the resources are more slender than would at first sight appear to mining engineers making a cursory examination.

Mr. H. ST. JOHN DURNFORD, in moving a vote of thanks to Mr. Gascoyne for his paper, said that the author's last remark might be true that there was not so much coal there after all. The price of 10s.

to 12s. per ton—as the coal had to be put into bags—was not so good as it seemed, as gold was less valuable there than here.

Mr. E. W. THIRKELL, in seconding the motion, said that the paper would repay careful study. The Transvaal was now attracting a great deal of attention, and the coal seemed to be remarkably free from sulphur, which was rather an important point. Another important feature showed that the coal, which in this country always rested upon a bed of fire-clay, which they were led to believe was the ancient soil, did not seem to be formed on those lines in the Transvaal.

ANNUAL GENERAL MEETING.

Mr. HALL moved “that the Council be desired to consider what is the best date, hour, and place for the annual meeting.”

Mr. NEVIN seconded the motion.

The resolution was carried.

The annual dinner was held in the evening at the King's Head Hotel.

SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE
INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,
HELD IN THE MASON COLLEGE, BIRMINGHAM, JULY 15TH, 1897.

MR. W. J. HAYWARD IN THE CHAIR.

The minutes of the last General and Council Meetings were read and confirmed.

The following gentlemen were elected :—

MEMBERS—

Mr. HENRY CROFT, Assoc. M. Inst. C. E., Victoria, British Columbia.
Mr. SAMUEL G. PEARSON, 17, East Bank, Stamford Hill, London, N.

STUDENT—

Mr. LEONARD MUNN, Camborne, Cornwall.

DISCUSSION ON MR. E. J. BAILEY'S PAPER ON "SAVING
LIFE IN COLLIERY EXPLOSIONS." *

Mr. W. B. SCOTT (H.M. Inspector of Mines) said that Mr. Bailey recommended "stations" to protect men from the consequences of outbursts of firedamp, but he did not appear to describe what a "station" was, and whether they would be difficult or costly to maintain.

Mr. E. J. BAILEY said that his idea was that pipes should be laid to a certain point in a road where men could make themselves temporarily safe; he certainly thought it would be desirable for the pipes to be taken into a closed chamber of some kind, but he had not gone into the details of the "station." Mr. F. Delafond had written a paper† in which measures calculated to preserve the men from the consequences of sudden outbursts of firedamp were passed in review, and amongst them was a

* *Trans. Fed. Inst.*, vol. xiii., page 133.

† *Annales des Mines*, 1897, vol. x., page 653; and *Colliery Guardian*, 1897, vol. lxxiv. page 61.

similar plan to that suggested in his paper. He recommended that in positions behind the working-face, compartments should be placed for introducing fresh air, and in which the men might take refuge. If such compartments or stations were placed in mines, the men would certainly have a better chance of escape.

The CHAIRMAN hoped that Mr. Bailey would be able to give further information as to the practicability of the plan he proposed for adoption. The precaution recommended by Mr. Bailey was undoubtedly worthy of serious consideration.

THE FEDERATED INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,
HELD IN THE ROOMS OF THE ROYAL UNITED SERVICE INSTITUTION, WHITEHALL,
LONDON, JUNE 3RD, 1897.

MR. LINDSAY WOOD, PRESIDENT, IN THE CHAIR.

PRIZES.

The SECRETARY announced that the Council had awarded prizes of books to the writers of the following papers, which had been published in volumes x. and xi. of the *Transactions*:—

- "The Causes of Death in Colliery Explosions." By Dr. John S. Haldane.
- "Geological Description of the Gold-mines of the Transvaal." By Prof. L. de Launay.
- "The Depth to Productive Coal-measures between the Warwickshire and Lancashire Coal-fields." By Mr. C. E. de Rance.
- "Photography in the Technology of Explosives." By Mr. Alfred Siersch.

The PRESIDENT (Mr. Lindsay Wood) delivered the following address:—

PRESIDENTIAL ADDRESS.

By LINDSAY WOOD.

It is the duty of your President to deliver an address to the members of this Institution at the June meeting in each year. Before doing so, I must, in the first place, thank you for the great honour you have done me in electing me your President, and I trust that I may be able, with the assistance of the Council and the officials, to carry on the work of the Institution to your satisfaction and to its increased prosperity and greater utility.

To prepare an address worthy of being laid before a body of gentlemen such as constitute the members of The Federated Institution of Mining Engineers is a very difficult matter, and one which I feel quite inadequate to satisfactorily perform.

I think that it is the duty of a President of an Institution such as this to carefully consider the objects for which the Institution has been formed, and to use his best endeavours, with the assistance of the Council, to see that those objects are carefully carried out for promoting the greater utility of the Institution. In order to do this, it is necessary to look back into the past history of the Institution to see what work it has done, and whether anything which ought to have been done has been neglected. It will not be sufficient merely to review the number of papers which have been read and the character of the discussions which have taken place. I think we must go further than that; we must see whether or not the reading of these papers and the discussions which have taken place on them have had any, and what, effect in promoting the advancement of the sciences with which we are so intimately connected.

The Institution was formed in 1889, eight years ago, its chief object being to promote the advancement of the sciences of mining, geology, metallurgy, engineering, and their industrial applications. Previous to that date, there were in existence several institutions of a similar character. It was, however, believed that a federation of these institutions would have a very beneficial effect in promoting the advancement of

the great work which they all had in view, and this opinion was entertained from the earliest formation of institutions of this character, for the late Mr. Nicholas Wood (my father), in his (first) Presidential Address to the members of the North of England Institute of Mining and Mechanical Engineers in 1852, referred to such a scheme. The late Sir George Elliot in 1868, Mr. John Daglish in 1886, Mr. T. W. Bunning and Sir Lowthian Bell all spoke in favour of it; and I think, if we carefully review, in the first place, what I may call the literary work of the Institution, we have every reason to be satisfied with the high character and great utility of the papers which have been contributed by the members, and the very interesting and instructive discussions which have taken place on them. It would be impossible for me in an address of this character to give a review of the various papers which have been read, but if proof were wanting of the value which the professional members of the coal and engineering trades set upon the *Transactions* it would be shown by the fact that since The Federated Institution of Mining Engineers was formed, the number of members has increased from 1,239 to 2,382, or nearly double. A portion of this increase is due to two local institutes having joined The Federated Institution of Mining Engineers in addition to the four which first formed the federation, but it is to be presumed that they would not have joined unless they had seen the great advantage which their members would obtain by so doing; therefore the statement that the number of members has practically doubled during the first seven years is a correct conclusion to be drawn from the facts I have quoted.

There are still some four local associations which have not yet joined this federated institution, but I hope that they will soon see how great an advantage it will be to their members to do so, and that ere long we may not only have the advantage of their membership, but that their members will have the advantage of being associated with us. We must all be of opinion that the larger the area from which information on the very great variety of subjects relating to the profession of mining and mechanical engineering is obtained and the larger the area through which that knowledge is circulated, the greater must be the benefit accruing to the proficiency of these professions.

Previous to the formation of this Institution, the members of the various local associations read papers which were discussed and circulated only amongst the members of the local association, and the facts, ideas, and valuable information contained in those papers did not, in a very large majority of cases, ever come to the knowledge of the members of

the mining profession in other districts. Thus these members were not only deprived of this information, but the information itself was rendered less valuable by not being so widely known as it should have been. By the formation of The Federated Institution of Mining Engineers this defect has to a great extent been obviated, because not only the papers which are read before The Federated Institution of Mining Engineers but those which are read before the local associations are circulated among the members of the federated societies, thus giving a very wide circulation to the valuable contributions and discussions which take place. I therefore again venture to hope that those local associations which are not now federated with us will soon see their way to remove any existing obstacle, financial or otherwise, which now prevents them from joining our Federation.

In order to form a somewhat correct opinion of what has been the effect of the formation of these various mining and engineering institutions, we must look back on what was the state of the mining and mechanical professions as relating to mining engineering when these institutions were formed, and compare that with the present state of proficiency. I cannot of course contend that the whole of the increased proficiency, which I hope I shall in a later part of this address be able to prove has accrued, is entirely due to the formation of these institutions; but it is undoubtedly due to the increased education, not only of the managers of mines, but also to that of the under-managers and all classes of the management, as well as to the workmen themselves. At the same time I am sure that the mining and mechanical institutions have been the means of disseminating amongst the managers and under-managers of mines knowledge of a technical character which they would not otherwise have obtained.

This year, 1897, which is one of great mark in the history of our country—being the sixtieth year of the reign of H.M. Queen Victoria—has induced many of us to look back on the vast advance which has taken place during that eventful period, both as regards the education of the people, the increased prosperity and happiness of all her subjects, and the vast advance which has been made in all branches of science. Great as these have been, I think that the science of mining in all its various branches will be found to have advanced in a ratio equal to that of other professions.

Let us look very shortly at what some of the advancements made in mining science have been. It is, I fear, impossible to form an accurate

comparison of what was taking place in mining so far back as 60 years ago, as there were few, if any, statistics kept at that time, and therefore we must be satisfied to make comparisons with a less remote period of time than that.

A mining engineer has two great objects to perform, on which hang all the other minor details of his profession. The first is to work his mines with the least possible loss of life or injury to the workmen employed by him : this is his first and chief object. The second is to produce the minerals he is working at the least possible cost, having his first and chief object always in view. Let us therefore see what has been the advancement made in saving of life during the period for which we have reliable statistics with reference to loss of life, accidents, and other causes.

We find, by the official returns, that the death-rate per 1,000 persons employed in and about the mines in the United Kingdom was, on the average of the years 1851 to 1855, 4·294 ; but in the year 1896 the death-rate was 1·480 per 1,000 persons employed. This shows that if the same death-rate that existed in 1855 had continued to exist to the number of persons employed, in 1896 there would have been 2,000 more deaths than there have been, of which 1,982 deaths have been saved on those employed underground, and only 27 on those employed on the surface. However great and satisfactory this saving of life may be, there is still ample scope for a further large reduction in the number of deaths which still take place in our mines.

When we examine the class of accidents which caused the deaths during various years we find that they were as follows :—

Classes of Accidents.	1873.		Five Years, 1873-1877.		Five Years, 1891-1895.		1895.		1896.	
	No. of Deaths.	Percentage of Total Deaths.	No. of Deaths.	Percentage of Total Deaths.	No. of Deaths.	Percentage of Total Deaths.	No. of Deaths.	Percentage of Total Deaths.	No. of Deaths.	Percentage of Total Deaths.
Explosions ...	100	9·35	199	18·06	141	13·43	55	5·28	173	16·88
Falls of stone ...	491	45·93	452	41·02	438	41·72	426	40·88	424	41·36
Shafts ...	171	15·99	151	13·70	97	9·23	97	9·30	68	6·64
Miscellaneous ...	221	20·66	199	18·05	257	24·48	345	33·10	237	23·12
Surface...	86	8·04	101	9·17	117	11·14	119	11·44	123	12·00
Totals ...	1,069	100·00	1,102	100·00	1,050	100·00	1,042	100·00	1,025	100·00

	1873.	1895	1896.
No. of persons employed under-ground	407,808	564,638	557,026
No. of persons employed on surface	106,341	135,646	135,658
Totals	514,149	700,284	692,684

	Tons.	Tons.	Tons.
Coals	128,680,131	189,652,562	195,351,951
Fire-clay	1,742,193	2,314,983	2,526,044
Ironstone	12,094,827	7,231,835	7,856,586
Oil-shale	524,095	2,246,865	2,419,525

From these tables it will be seen that the number of deaths from explosions which took place in 1895 was very small, viz., 55, and only 5·28 per cent. of the total lives lost. I regret, however, to say that the lives lost from this cause in the year 1896, the returns for which have just been published, show that 173 lives were lost last year, being 16·88 per cent. of the total deaths during the year.

Although the average number of deaths caused by explosions has decreased by 90 per annum, taking the 5 years' average of the years ending 1855 and compared with the 5 years ending 1895, or 39 per cent., it must, however, be borne in mind that the number of men employed underground has very largely increased. Taking the average of the 5 years 1851-5, compared with the 5 years 1891-5, the increase of those employed underground has been rather more than three times. The numbers are: 1851-5, 182,427; 1891-5, 575,199; and therefore the risk of accident occurring has greatly increased. But if we compare the average number of deaths by explosions for the 10 years between 1873 and 1882, we find it is 262 annually, whereas that for the last 10 years ending 1896 it has been an average of 150, or a decrease of 42·75 per cent.

The causes which have led to this saving of life, which were due to explosions of gas, are no doubt better ventilation of the mines by the increased volume of air obtained by mechanical means, which is now so largely used instead of the old system of furnace, and by the better application of air to the various working-faces due to the more perfect knowledge of the theory of ventilation. The more general use, I might almost say the universal use, of safety-lamps in all parts of the mines; and the safer and more perfect description of lamp now being used, and the better condition in which they are kept, has also conduced to saving of life.

There is another cause, which perhaps more than any other has led to a decrease of accidents caused by explosions and that is, the diminished amount of blasting which takes place in mines now compared with former usage, and the almost entire cessation of the use of gunpowder in mines which are liable to produce gas. This change has been brought about by the greater knowledge of the very important part that coal-dust bears both with respect to the origin and the intensity of explosions. In the year 1876, Mr. Wm. Galloway drew the attention of the Royal Society to the dangerous effect of a mixture of coal-dust in the air with a small percentage of gas in causing explosions, and increasing their destructive effect. In November, 1878, Messrs. Freire-Marreco and D. P. Morison read a paper before the North of England Institute of Mining and Mechanical Engineers giving an account of their experiments at Elswick colliery, which went to prove that an explosion could be obtained under certain circumstances by coal-dust and air without any mixture of gas. Since that time great attention has been given to the subject, and many experiments have been made and information obtained which show that blasting with gunpowder in strong currents of air where there is accumulation of dust is very dangerous, and there is, I think, little doubt that many explosions which took place in years gone by, the cause of which could never be accounted for, arose from or were greatly aggravated by the presence of coal-dust.

In view of the facts obtained by the experiments and investigations made by members of the various mining and mechanical institutions which went to prove that a blown-out shot charged with gunpowder possessed all the elements for causing an explosion of dust and air, it became necessary to find some other blasting material than gunpowder, which would not ignite a mixture of gas, coal-dust and air, or even coal-dust and air.

A committee of members of the North of England Institute of Mining and Mechanical Engineers was formed in 1888 for the purpose of testing the various so-called flameless high explosives of nitro-glycerine and other compounds which had been invented. A very valuable report on the subject has been drawn up and communicated to the members of the Institution, and I think we have every reason to believe that the more universal use of safety-lamps, the use of high explosives for blasting, and the use of water in the places which are dry and dusty where the shot has to be fired, will greatly reduce the number of deaths which are now annually caused by explosions.

The second class of accident, and by far the largest source of loss of life in mines, is caused by falls of roof and sides. These accidents constitute 41 per cent. of the total deaths, and are by far the most difficult to prevent, as their occurrence is not due to want of knowledge or of scientific attainments on the part of the management, but are due in many cases to a want of care and exercise of practical experience on the part of the workmen themselves. I think that the only way by which this class of accidents can be reduced is by having this work, and especially the most dangerous part of it, namely, the drawing of the timber, performed by experienced and special workmen, trained and appointed for that purpose. I do not of course mean that a workman should be relieved from the necessity of protecting himself and rely entirely on this special class of timberers: this, I think, would be a source of danger rather than a means of prevention of accidents. It would be impossible to have an experienced timberer always present with each workman, and as many descriptions of roofs are liable to crack and fall at any time, it is essential that the workman himself should watch the roof and set timber to protect himself. It is not therefore to the work of such institutions as the one I am now addressing—The Federated Institution of Mining Engineers—that we must look for the prevention of this class of accidents, but rather to the increased experience and personal care of the workmen themselves.

The third class of accident is that connected with shafts. This is a class of accident which is much more under the control of the management than those caused by falls of stone. Improved engineering, both as regards the mechanical engineering and control of the winding-engines, and the proper laying out of pit-heads so as to prevent men and materials from falling down the shafts, are matters which can be governed by the skill and scientific attainments of the managers of mines. There is perhaps no part of the engineering of mining plant which has made such progress as winding-engines. Forty years ago they were almost entirely of a small class, running slowly in the shafts, lifting small weights, and a small number of men riding in cageloads. They were usually beam-engines with upright cylinders, the valves being worked by tappets and spanners, which were difficult and laborious for the engineman to handle. We now have winding-engines running at very high speeds, lifting great weights and a large number of men at a time. It is no uncommon thing for the cages to attain a speed in parts of the shaft of 40 miles per hour, and lifting a weight of coals, cage, and rope of 18 tons. Con-

sidering that there are upwards of 550,000 persons employed underground, who descend and ascend the pit-shafts each time they go to work, which will certainly not be less than 200 times per annum, there will have been at least 200,000,000 journeys performed by this number of workmen up and down the shafts in 12 months ; and, seeing that only 30 lives have been lost per annum on an average of 5 years from all causes connected with travelling in shafts, there does not seem to be much room for improvement in preventing this class of accident. Moreover, out of the 30 deaths per annum due to shaft accidents, only 2·4 per annum occurred from over-winding. This fact, I think, speaks very highly for the careful attention which has been given by winding-enginemmen to their duties. Although it is impossible to estimate with any degree of accuracy the number of journeys which the cages must have run with workmen in them, yet the average of only 2·4 lives per annum being lost by over-winding out of the 550,000 persons who descended and ascended the mines almost daily is surprisingly small.

Of the fourth class of accidents, which are enumerated under the head of "miscellaneous," there seem to be three heads under which the majority of these accidents take place, namely, by explosions not due to explosions of gas and coal-dust, and those accidents which take place on incline and engine-planes, and thirdly by trams and tubs : the two latter may be classified under one head for the purposes of this address. From the first, namely, explosions other than those of gas and coal-dust, and which I suppose arise from blasting-material, these constitute about 20 per annum, and although we have no statistics to show how many men use blasting-material, the number does not seem large, and judging from the statistics of the district with which I am more immediately connected, there is little doubt that these accidents are almost all due to the carelessness of the persons handling the materials.

The other two sub-classes, namely those which occur on railways and by trams, constitute a large proportion, and are on an average of 152 per annum. These accidents are of a class which depend on care and supervision for their prevention, and, as such, are capable of improvements rather than dependent on scientific attainments, which may be obtained by the dissemination of knowledge, such as institutions similar to this can afford.

I have now given an account of the various accidents causing loss of life in our mines, of the reduction in loss of life which has taken place

during the last 25 years, and the important part which I consider the scientific institutions which have been formed in all parts of the United Kingdom, many of which are now federated with us, have had in bringing about the present improved state of affairs. There is, however, another change which has taken place of late years in the general system of education which, I think, is having a very beneficial effect, especially amongst those who are growing up to be managers of mines. I refer to technical instruction. Great Britain, until the last few years, has been greatly behind continental countries in this important branch of education, but we now have within easy reach of anyone desiring to benefit by this class of instruction, classes in almost every village carried on under the control of the various county councils, and in addition to these local classes, we have several highly efficient science colleges, such as Owens College, Manchester ; the Durham College of Science, Newcastle-upon-Tyne ; the Yorkshire College, Leeds ; the Firth College, Sheffield ; and several others, all of which are largely attended and are doing a work which must have a very beneficial effect not only on the mining industry, but also on the future prosperity of this great commercial country.

With all these great advantages, which the rising generation now have, it is to be hoped that there will be a still further saving of life in the working of our mines.

In the early part of my address, I stated that I considered the second important duty of a mining engineer was that of working his mines on the most economical principle and at the least possible cost, having due regard to the first duty, namely, freedom from accidents.

It is exceedingly difficult, if not impossible, to say what has been the increased cost of working the coal-mines in Great Britain during the last 20 or 30 years, as there are no reliable public statistics kept on this matter. But if we look at the figures which we have from the official returns for the years 1865 and 1895—I have taken the former date because it goes back for a period of 30 years from the present time—we find that in 1865 there were 250,784 persons employed underground, producing 98,100,000 tons or 391 tons per person per annum ; whereas in 1895 there were 584,298 persons employed underground, producing 189,700,000 tons, or 325 tons per man per annum, or a decrease of about 65 tons per man per annum, equal to 16·88 per cent. reduction in the output per man. Therefore it would have required 51,062 more men in 1895 to produce the same quantity of coal as was produced in 1865 ; and taking the cost of each person employed underground at £60 per annum

there would have been paid for underground labour alone in 1895 £3,064,000 more than there was paid in 1865 for the same quantity of coal. On the same basis of calculation, it required one surfaceman for each 1,517 tons of coal per annum in 1865, and it required one surfaceman for every 1,270 tons per annum in 1895, thus requiring 12,577 more men in 1895 than in 1865 to produce the same quantity of coal, and taking the cost of a surfaceman at £45 per annum, it would require £566,000 more wages to be paid in 1895 than in 1865 to produce the same quantity of coal; consequently the cost of above- and below-ground labour alone is £3,630,000 per annum more in 1895 for the same quantity of coal than it was in 1865.

It is clear, therefore, that there has not been any saving in the cost of labour since 1865. The cause of this largely increased cost is no doubt largely due to the legislation which has taken place with reference to mines, as well as the effect of the combination of workmen. Since 1851 there have been five special Acts of Parliament passed for the regulation of mines, all of which have been the means of increasing the cost of production of coal, and there is now under the consideration of Parliament an Act which will further considerably increase the cost of working the mines in this country, and which is based on an entirely new principle of law.

If this large annual expenditure were necessary for the protection of life and prevention of accidents to those engaged in the working of our coal-mines, there is not, I am sure, a single coal-lessee who would not gladly pay the increased taxation; but a large amount of it is not required for that most desirable object, and I venture to think that it would be well for the government of this country to look carefully into what will be the result of this continual increase of taxation on the future working of our coal-mines, on which the prosperity of our great manufactures so largely depends.

The result of this increased cost which is being imposed on coal-working is undoubtedly beginning to take effect in the abandonment of many of the thin and hard seams of coal, and, when once abandoned, they will, in all probability, never be capable of being re-opened on account of the incalculable injury done to them by the accumulation of water and the crushing that they receive during abandonment; thus entailing a national loss of a very large quantity of mineral.

Mining engineers of the present day, as demonstrated by the papers contributed to this Institution, are using great energy, perseverance, and determination to reduce these increased costs by greater scientific

knowledge, the application of mechanical appliances and improved machinery to the working of our coal-mines, but they certainly do not receive much encouragement from the almost annually increased burdens which are cast upon them.

With these few and inadequate remarks I must again thank the members for electing me as President, and I trust that this Institution will long continue and carry on the great and useful work for which it has been formed.

Mr. A. M. CHAMBERS (Sheffield) in moving a vote of thanks to the President for his address, said that Mr. Wood had done The Federated Institution of Mining Engineers an honour in consenting to take the presidency for the present year ; he had been President of the North of England Institute of Mining and Mechanical Engineers ; his father was the originator of mining institutions, and also of the Mining Association of Great Britain ; and he was looked back to as one of the fathers of the coal trade—one of the men who saw beforehand what was required. The President's address was another evidence of the manner in which he examined all questions connected with mining engineering and of the careful way in which he marshalled facts and placed them before the members.

Mr. M. H. MILLS (Mansfield) had great pleasure in seconding Mr. Chambers' proposal. Mr. Lindsay Wood was well known in all parts of Great Britain, and nothing that he could say would enhance Mr. Chambers' remarks.

The motion was warmly approved, and briefly acknowledged by the President.

Mr. LESLIE S. ROBINSON read the following paper on "Light Railways" :—

LIGHT RAILWAYS.

By LESLIE S. ROBINSON, Assoc. M. Inst. C.E.

Definition.—The term “light railway” is often used with a good deal of looseness, and it is no easy task to give a comprehensive and at the same time an exclusive definition of a light railway. A light railway is not necessarily a narrow-gauge railway, though very frequently it is built to a narrower gauge than the normal standard gauge. This is especially the case on the Continent, where the metre and 2 feet 6 inches gauges are extensively used. The writer would define a light railway as a line laid with lighter rails, less heavily ballasted, and adapted for carrying a lighter class of rolling stock at a slower speed than is in use on main railway-lines, whatever gauge may be employed.

A light railway must, moreover, be freed from the restrictions imposed upon standard railways, rendered necessary by the high rates of speed in vogue upon them, and the congested nature of the traffic; but these restrictions are quite unnecessary for the slow speeds and smaller traffic existent on a light railway.

Signals should be reduced to a minimum, if not entirely suppressed, heavy cuttings and embankments avoided, while the gradients can be steeper and the curves of smaller radius. Stations and buildings will not be required, with the exception of sheds to protect the more perishable goods from the inclemency of the weather, and, in fact, everything must be carried out in the cheapest and simplest way possible.

General Reasons for their Adoption.—One of the principal reasons in favour of a light railway is that, owing to its lower cost, communication can be established in districts which would be totally unable to support what we may call a standard railway, encumbered with the numerous restrictions imposed upon it by the state, with a heavier class of works and permanent way, fencing, etc., rendered necessary by the greater speed and weight of the rolling stock. But owing to the comparatively small cost of a light line new countries can be opened up, which would otherwise be kept back for years, or even generations, if they had to wait for the construction of a standard railway.

The employment of a narrower gauge than the normal would seem to be particularly advantageous for agricultural districts, due to the facility with which branches can be laid into farms along the route and the waggons loaded on the spot, thus dispensing with the necessity of a long cartage and ultimate transshipment into the railway-waggon at the nearest railway-station.

There is another important point in connexion with railways of a narrower gauge and lighter rolling stock that must not be overlooked, namely, the much larger proportion that the gross load bears to the tare of the waggon ; or, in other words, the proportion that the paying load bears to the total load is very much increased. The ratio of tare to gross load varies between $\frac{3}{4}$ and $\frac{1}{4}$.

The narrow-gauge, moreover, adapts itself far more readily to the varying nature of any country than does the broad-gauge.

Continental Light Railways.—The author was asked to accompany the Commission nominated by the Cape Government to report upon light railways with a view to their introduction into Cape Colony, and had the opportunity of visiting the leading light railways on the Continent.

Caen, Dives, and Luc Line.—The first line visited by the Commission was the Caen, Luc-sur-Mer, and Dives line. This line is of 2 feet gauge, and runs from Caen in Normandy to Dives and Luc-sur-Mer, at both of which places there is a junction with the Western of France Railway. The steepest gradient is 1 in 88, and the sharpest curve is 66 feet in radius.

The width of formation is 9 feet 9 inches and ballast is 6 feet 10 inches by 1 foot, and requires about $\frac{3}{4}$ cubic yard to the forward yard.

At the termini at Dives and Luc-sur-Mer, the narrow-gauge lines run parallel to the normal gauge, but are raised about 18 inches above them for convenience of transshipment. The cost of transshipment amounts to 2d. per ton, which is paid by the receiving company.

The line is laid with 30 lbs. rails, riveted to steel sleepers, which has the advantage of greater rigidity for a given weight of rail and sleeper. The total weight of permanent way is 89 lbs. per lineal yard.

The line runs along the side of the main roads and alongside a canal : there being an entire absence of fencing, etc. The cost of construction, including rolling stock, stations, telephones, etc., was £2,148 per mile. The profits earned by the company have increased steadily year by year, and realize 7 per cent. on the capital.

Belgian Light Railways.—The Commission next visited Belgium, but before describing more particularly the various lines visited, it may not be out of place to say a few words on the general working of light railways in Belgium.

The light railways of Belgium are under the control of the Société Nationale des Chemins de Fer Vicinaux, which has the preferential right of constructing any light railway in the country, provided the government consider that the line will be beneficial to the districts through which it passes.

The capital is found by the state, the provinces, the communes, and a small portion by private individuals, and no railway can be made until sufficient capital has been found to ensure its construction and equipment. The share capital, which represents the cost of constructing the lines and, if necessary, equipping them with rolling stock, is divided into a number of shares, of which the state, communes, and provinces must contribute at least two-thirds. After the line has been working for 19 years, the state, provincial, and communal authorities have the right to buy, at par, the shares originally subscribed by individuals.

The society is managed by a council consisting of a president (nominated by the government), four administrators, and a director-general. A separate account is kept of the total cost, receipts and expenditure of each line; and the share of the general expenses of the company to be borne by each line is regulated by the amounts of the receipts that it contributes. When a line is worked at a loss, the deficiency is made good by the society and repaid out of the first profits made on the line. This system of centralization considerably facilitates the promotion of light lines and greatly reduces the expenses attendant thereon.

Brussels to Ixelles.—The line from Brussels to Ixelles forms part of the street tramways of Brussels. In the streets of Brussels, the rails are 60 lbs. to the yard and are provided with guard-rails, but in the country only 40 lbs. rails, without guards, are used.

The engines on this line are completely enclosed, as is the case with most of the Belgian light railway-engines. The heaviest engine at present in use weighs 24 tons. Speed in thoroughfares is about 6 miles per hour; in the country, however, a speed up to 20 miles an hour is allowed.

One noticeable point in this line is the reversal of the train at Ixelles. The train runs on to a loop line having very sharp curves, with the entrance and exit at the same pair of points.

The author thinks it may be as well to give here, while dealing with the Belgian light railways, an example of a purely agricultural line, which depends very little on its passenger traffic and chiefly upon the carriage of farm-produce. The following particulars are drawn from Major Addison's report :—

Andennes to Eghée.—This line is constructed almost entirely upon the high road, except where heavy gradients render slight deviations necessary. The line is laid at one side of the road and raised slightly by ballast, being separated from the remainder of the road by a kerbstone. It looks indeed like a footpath but is not used by vehicles or pedestrians.

Where sidings are required, the running line deviates from the road for a short distance, while the line along the road is used as a siding, and carts can draw up in the road either to load or unload the waggons. Points are worked in the country by a lever and in the town by a special key.

Curves as sharp as 100 to 130 feet radius are in use and ties are used to prevent the rails from opening out. The rails are of vignolles section, secured by dog-spikes to creosoted sleepers 4 feet 8 inches long, 8 inches wide, and 4 inches thick.

Hennef to Asbach.—The next line of any particular interest inspected by the Commission was that from Hennef to Asbach, and is of special interest to the members of this Institution on account of the heavy mineral traffic.

The line is very substantially constructed both as regards bridges and permanent way, and is laid with 30 lbs. rails on wooden sleepers. The ruling gradient is 1 in 60. The greater portion of the traffic on this line, which is of a very heavy character, being principally road-metalling, is down the gradients, which enables the line to be worked very cheaply. At the lower terminus, the small trucks run on to elevated platforms and tip into the broad-gauge trucks.

The length of the line is $24\frac{1}{2}$ miles. The gauge is 2 feet 6 inches, and the rails are laid on wooden sleepers 4 feet 6 inches long, 7 inches wide, and 5 inches thick. The life of the sleepers varies from 8 to 12 years. The tare of the waggons in use on this line averages about one-third of the gross load.

The cost of construction, due to the extremely substantial manner in which the line was constructed, was £4,000 per mile, while the cost of maintenance amounts to about £22 per mile. The line pays a dividend of 7 per cent.

This line demonstrates that mineral traffic can be served with advantage, and also with financial success, by a light railway of narrow gauge working in conjunction with a standard-gauge line.

Hainsberg to Kipsdorf.—This line, of 2 feet 6 inches gauge, running from Hainsberg, which is $6\frac{1}{2}$ miles from Dresden, to Kipsdorf through a very pretty and mountainous district, has a considerable pleasure traffic in summer. It is under the control of the state, and is substantially constructed throughout, having steel bridges, station-buildings, etc. It has no signals, but is worked by a telegraph system extending the whole length of the line. The line was originally laid with 30 lbs. rails on wooden sleepers 5 feet long, 7 inches wide, and 5 inches thick; but they are gradually substituting 35 lbs. rails for the 30 lbs. rails originally used. Unlike the Belgian railways, this line does not run along the public road, but runs across country. The ruling gradient on the main line is 1 in 30; but on the branch-lines it is rather less, being 1 in 33. The sharpest curve is 165 feet radius, and the average speed is 15 miles per hour. It carries on an average 260,000 passengers and 46,000 tons of goods per year, and in 1894 a dividend of 5 per cent. was paid on the capital. One of the principal items of the goods traffic is the milk-supply of Dresden, which is largely carried by this line. The tare of the waggons amounts to half of the gross load. All the trains are fitted with the Heberlein brake. The cost of construction was £6,400 per mile. Three classes of locomotives are in use, *viz.* :—18 tons simple, 26 tons compound, and 28 tons Fairlie.

Klotzsche to Königsbrück.—The principal feature of this line, which is owned by the state, is the transshipment at one of the termini, which is effected on the cradle system. The line communicates directly with a large pottery; and as it would be highly detrimental to the goods to unload them at the junction of the broad and narrow-gauge lines, the broad-gauge waggons are placed on transporters or cradles, and run into the factory, and the pottery can thus be taken to its destination, both over the narrow and broad-gauge, without transshipment. The ordinary methods, by crane and by hand-labour, are also in use on this line, as well as that of running the waggon up an incline and tipping.

Ferdinandshof to Friedland.—The next line visited by the Commission was in complete contrast to the preceding line, having been constructed in the first instance as an extremely light agricultural line of the very cheapest and roughest kind, to serve several beet-sugar factories. The line is 16 miles long, forming part of a 2 feet gauge system, 75 miles in length, and is laid with 17 lbs. rails on wooden sleepers. Sidings run into all the neighbouring farms, and the cars are small wooden platform-waggons with wooden sides. The wheels of the rolling stock are all double-flanged, and the crossings are made to suit them. The steepest gradient is 1 in

50, and the sharpest curve of 165 feet radius. The cost, inclusive of rolling stock and purchase of land, barely amounted to £900 per mile. One difficulty, met with on lines constructed as cheaply as the above, with corresponding light rolling stock, is that the cars cannot be run in exposed places when very high winds prevail, on account of the side pressure exerted on them. This small light line has, however, proved itself so useful that they are now relaying the line with heavier rails and sleepers, and improving the class of rolling stock at a very considerable outlay.

Altena to Lüdenscheid.—This is a metre-gauge line owned by a company, but forced to comply with state regulations as it is state-aided. The line was originally laid with 30 lbs. rails upon longitudinal iron sleepers running parallel to the rails, similar to the method used on the Great Western Railway, but this proved unsatisfactory and the sleepers are now laid transversely. The earthworks are of a heavy and substantial nature, which accounts for the somewhat higher cost of the line, namely, about £5,000 per mile. They are gradually substituting 46 lbs. rails for the 30 lbs. rails originally laid down. The traffic comprised 184,385 passengers and 87,831 tons of goods in 1894. The steepest gradient on the line is 1 in 29. The capital of the company is £120,000, and $4\frac{1}{2}$ per cent. is paid on one class of shares and 1 per cent. on the remainder.

Break of Gauge.—Turning now to some of the more general questions in light railway construction, the break of gauge is a point that has given rise to an immense deal of discussion. It is pretty generally conceded by British engineers that a break of gauge is inadvisable where it can possibly be avoided, but abroad it has at least been proved that light railways with a break of gauge can be made not only successful from a technical and traffic point of view, but also from a financial one, and some of the continental light railways above referred to, may be instanced as examples. So much depends upon the local circumstances governing or controlling each particular case that no hard-and-fast general laws can be laid down on this much contested point, and each case must be carefully considered on its own merits.

It may be stated that where it is desired to open up a line of country or to develop an industry in which the receipts per mile will not permit of the construction of a standard gauge railway, it is preferable to construct a narrow-gauge line entailing a break of gauge rather than to postpone indefinitely, if not entirely, the development of the country or

the industry until such time as the receipts per mile would justify the construction of a standard gauge line.

The chief objections to a break of gauge are briefly the necessity for :—(1) Transshipment ; and (2) duplication of types of rolling stock and locomotives, so that rolling stock which is too antiquated for use on the main line, but which would serve admirably on a secondary line cannot be used on account of the smaller gauge.

(1) Transshipment is a point that has been made a good deal of—not to say too much of—by the opponents of the narrow-gauge system. There is no doubt that transshipment is a decided drawback and should be avoided on all possible occasions. But transshipment must take place and is taking place daily on main lines without much notice being taken of the same. For instance, the farm produce, fruit, etc., from Normandy and Brittany, which has to go through between four or five distinct transshipments, is put on the London market in a better condition and at a cheaper rate than the farm produce from our own home counties. It is not therefore the transshipment of the goods that prevents British farmers from competing with their foreign competitors. The inconvenience of transshipment, moreover, depends very largely on the nature of the goods to be transshipped, and an extra cost of 1d. or 2d. per ton is not a very serious matter. It is preferable to have a narrow-gauge line with transshipment than to have no line at all, and in many cases even with the transshipment from a narrow-gauge to the standard line the actual number of transshipments between the producer and consumer is not greater than without a break of gauge, since the narrow-gauge cars can load the goods where they are actually produced, thus avoiding the carting and subsequent transshipment into the main-line cars. Another advantage which to some extent counterbalances the disadvantages of transshipment is that one farmer alone is rarely able to completely fill a broad-gauge waggon with his own farm-produce ; whereas this difference does not exist with the narrow-gauge rolling stock, and the contents of two or three narrow-gauge cars will completely fill a standard-gauge truck, thus enabling the main line company to offer the farmer better terms and to work its rolling stock to better advantage.

In dealing with the matter of transshipment of minerals, in which the members of this Institution are more particularly interested, it may be said that, although they are somewhat deteriorated by transshipment, yet when the junction of the narrow-gauge with the standard line is properly designed for that purpose, this transshipment can be effected with considerable ease, and at a comparatively small cost. Still, the fact must not

be overlooked that the transshipment of large quantities of minerals is and must remain a very serious matter.

The transshipment of general merchandise is carried out either by crane or hand labour. In the first case, the skips or packages are lifted from the narrow-gauge cars and dropped into the main-line trucks. In the second case, the rail-level on the narrow-gauge line is raised slightly above that of the normal gauge, thus bringing the platform of the two cars on the same level, and the goods are transhipped straight by hand from one car to the other.

On several of the Continental lines, a system is in use by means of which broad-gauge wagons are carried on narrow-gauge lines, thus avoiding altogether the risk of damage by transshipment. The system may be briefly described thus:—At the junctions, the narrow-gauge lines are run into a pit (between the standard-gauge lines), which is of such a depth that the platform of the bogie trucks when placed underneath the main-line wagon is just below the flanges of the wheels, so that while the tread of the wheel of the standard-gauge waggon is still on the rails, the flange is slightly above the platform of the narrow-gauge bogie. The main-line rails at the narrow-gauge end of the pit have a drop of about 1 inch, so that when the wheel of a standard-gauge waggon passes over this drop and leaves the rail, the flange becomes firmly seated on the platform of the cradle-truck. The trucks are coupled together by chains to fit waggons of widely different wheel-bases.

The transporters used on the Hainsberg and Kipsdorf line are similar to the above described except that the weight of the waggon is supported by the axle upon two bogies running on the narrow-gauge line instead of upon the flange.

(2) If the light line is to act as a feeder to the main line there is no doubt that there is a considerable advantage to be gained by the fact that the older class of rolling stock can be used up on the light line. Against this, however, must be balanced the fact that a heavier rail will have to be used, that earthworks, etc., will be of a heavier and more expensive nature, that curves will have to be of greater radius on account of the locomotives and rolling stock, and that the line generally will not be able to run over the surface, as would be the case with a narrow-gauge line.

It has also been frequently urged that a break of gauge necessitates expensive repairing-shops on each narrow-gauge line. That this is not the case may be seen from the Continental light lines, upon most of which there is only one small shop containing a few necessary tools for small

repairs. Any extensive repairs that may be needed, and it is very seldom that such are required, are done in the main-line shops, the engines being mounted on trucks, and then run to the repairing-shop.

The weight per axle is a very important matter in the design of a light railway, and it is of great consequence that the weight per axle should be as uniform as possible, that the rolling stock should be so designed as to take full advantage of this maximum weight per axle, and that the weight per axle in the locomotives used on the line should not exceed the maximum weight decided upon. There are many instances in existence where this point has been largely if not entirely overlooked, and where the weight per axle in the locomotive is double that in the cars and the results have not proved satisfactory. Nowhere, so far as the author is aware, has the point been brought out with greater clearness than in the Barsi light railway designed by Mr. Calthrop, where the rolling-stock and locomotives are designed for a uniform load of 5 tons per axle.

The whole crux of the break-of-gauge question lies after all in the financial aspect. No one would hesitate to lay down a broad-gauge if the cost would allow of it, but when the question of constructing a light line has to be considered it is generally in relation to districts where the cost is of vital importance, and unless the line is likely to take a great development and eventually become an integral portion of a broad-gauge system the reduction of cost is an absolute necessity. It is not by choice therefore that an engineer would recommend a narrow-gauge were he given a free hand as to finances, but the question usually presents itself somewhat as follows :—

It is desired to establish some means of communication between an outlying district which requires to be developed and, say, a junction on the main line or perhaps a seaport. After carefully taking an estimate as to the traffic, the receipts per mile are arrived at, and upon these must depend very largely the decision as to whether a narrow or broad-gauge line can be constructed. If the receipts will only warrant an expenditure of say £2,000 a mile, it is futile to think of anything but a narrow-gauge railway. If a larger expenditure per mile is warranted, then it must be a question for decision in each particular case, according to the capital expenditure per mile, as to whether a light standard-gauge line should be constructed or one of the narrower gauge.

With regard to the cost it has sometimes been argued that after all the difference in cost for embankments and cuttings between a narrow-

gauge and standard-gauge railway is merely the small strip resultant upon the difference of gauge, which is naturally comparatively small if not insignificant. This argument has in some cases been given more prominence than it deserves, because with a standard-gauge line and rolling stock; even of a light type, the curves cannot be so sharp as in a narrow-gauge line; and therefore especially in mountainous districts, where on the standard line a comparatively deep cutting or high embankment would be necessary, on a light line the contour of the country may be taken advantage of and the cutting and embankment practically obviated.

The narrow-gauge railway certainly has the advantage over the broad in reducing the cost of land to be acquired, and also in being better adapted to profit by any spare land that may be available on the sides of the main road. The light lines further have the advantage in the reduced cost of sleepers, rails, ballast, etc.

This is well exemplified by an example given at the 1895 meeting of the International Railway Congress, of a Russian light line which cost, including rolling stock, £2,250 per mile, while a light railway of ordinary gauge would have cost £4,500 per mile, and an ordinary standard line would have cost £6,440 per mile. It need hardly be pointed out that the receipts per mile, which would produce a dividend on £2,250 per mile, could not do so had the expenditure been £6,440 per mile, while the receipts per mile would be more or less the same whatever the gauge.

Against these advantages, however, must be balanced the extra cost of rolling stock, repairing-shops, and cost of transshipment.

That light lines on narrower gauges are not the toys that they are sometimes made out to be and can earn ample dividends and carry a very considerable amount of traffic, both of goods and passengers, is very evident from the particulars given in the preceding pages and from the fact that over 800 miles already existed in Germany in 1894, over 1,000 in France, and over 600 in Belgium, and the dividend on these latter lines has been rising steadily year by year.

It is proved by Mr. Calthrop in his paper on the Barsi light railway that a narrow-gauge railway laid down at say one-fourth the cost of the standard gauge per mile is sixteen times more efficient as a revenue producer than a standard gauge line costing the same amount. The longer the run the greater the traffic and the more cheaply it can be worked.

Opinion in Great Britain appears to be against railways being worked by the state or public bodies as is the case abroad, no doubt due to the

fact that the railways in this country are controlled by large companies and not by the state as is the case on the Continent.

Whether it is advisable in colonial and in sparsely populated districts that the interest should be guaranteed by the state or that the capital should be subsidized by the state is too vast and complicated a subject to be entered into in a communication of the present nature.

Most Suitable Gauge.—If for the various reasons cited the standard gauge of 4 feet 8½ inches cannot be adopted, the question must naturally arise what is the next best suitable gauge? In answer to this query the author is of opinion that for this country every effort should be made to maintain the standard gauge, but that where such is absolutely out of the question a standard uniform narrow-gauge should be adopted. This would be a comparatively easy matter in the initial stages of light railway enterprise in this country and would prove of considerable benefit in later years from having standardized the rolling stock and so facilitated its exchange between different lines, and also that it would have the effect of standardizing the methods of transshipment.

Should the standard gauge of 4 feet 8½ inches be departed from, what the standard narrow-gauge should be may be a matter of opinion, but the author pointed out in the discussion on Mr. Pain's paper on light railways before the Surveyors' Institute as long ago as 1895* that where a standard gauge could not be used a 2 feet 6 inches gauge should, if possible, be adopted. He is glad to note that this is the gauge adopted, after careful study, by Mr. Calthrop on the Barsi light railway. In his paper read before the Society of Arts the latter writes as follows:—

There is no doubt that, as compared with all others, it is the gauge possessing the greatest carrying capacity per cent. of cost of track. It has sufficient stability to carry goods of very great weight and bulk, while the flexibility of its alignment is such that it can accommodate itself to country of the most mountainous and difficult character, at a fraction of the cost of a standard-gauge line negotiating similar difficulties.†

The author's opinion is further corroborated by the selection of the 2 feet 6 inches gauge by Mr. Mackay on the line designed by him in Cape Colony. A thoroughly substantial and roomy class of rolling stock can be designed for this gauge, as is evidenced by the class of rolling stock recently exhibited by the Barsi Railway Company at Newlay, Leeds, prior to its despatch to India.

Mr. Calthrop has drawn up in tabular form a summary of the working of all the Indian railways for 1895 obtained from the official

* *Trans.*, 1896, vol. xxiii., page 295. † *Journal*, 1897, vol. xlv., page 245.

reports, which shows that the average cost per mile of the standard 5 feet 6 inches gauge is £10,000, as against £4,500 for the metre and 3 feet 8 inches gauges, and £2,100 for the 2 feet 6 inches and 2 feet gauges. But while the working expenses of the 2 feet 6 inches gauge are slightly higher than those of the 5 feet 6 inches gauge (53·16 per cent., as against 45·14 per cent. of gross earnings), the percentage of net profits on total capital outlay is 7·67 in the case of the 2 feet 6 inches gauge, as against 5·78 in the case of the Indian standard gauge.

Conclusions.—It is somewhat difficult to arrive at any definite conclusion that would hold in all cases, for the reasons stated in the commencement of the present paper, namely, that the proper weight of rail, gauge, etc., to be adopted must be determined separately in each case, regard always being had to the special conditions surrounding that case; but it may be broadly stated that in circumstances where the receipts will not warrant the expenditure entailed by the construction of a standard line on the normal gauge, the light railway with normal or narrow gauge may be profitably constructed and successfully worked.

Further, the question of transshipment is not so serious a matter as to prohibit the construction of a light railway on a narrow gauge, because when the traffic is so heavy that transshipment is a very serious item the receipts per mile will nearly always warrant the construction of a normal-gauge railway. On the other hand, when the receipts do not warrant the construction of a standard normal-gauge line the amount of transshipment to be done would not in any serious way militate against a cheap rate of transit on that line.

Lastly, light lines on a narrow gauge can do, and are doing, good work in developing the land and industries of countries where they have been built which would in many cases have been left undeveloped to the present day had it not been for the light railways.

Mr. J. C. MACKAY (Ealing) wrote that he had read with much pleasure Mr. Robinson's paper on light railways, and agreed with the remarks thereon, with one or two exceptions. The paper discussed the subject in a common sense way, without bias in favour of any gauge—a rock against which most of the leading engineers stumbled. It was a matter for regret that the recent Act of Parliament relating to light railways did not define what the words "light railway" really meant, and did not state (if the standard gauge were not adopted) the gauge on

which narrower railways should be built. In this country he would define a light railway as one on the 4 feet 8½ inches gauge, laid with rails weighing 50 lbs. per yard, and with an axle-load of 8 tons. These conditions would allow of the present main line rolling-stock being used, with the exception of the locomotive engines; and the speed should be limited to 25 miles per hour. Of course the ballasting and road-bed would be of corresponding lightness, and the question of signals and passenger and goods accommodation would be decided by the amount of traffic. If such a line were not financially possible, then an alternative railway, on the 2 feet 6 inches gauge, with rails weighing 30 lbs. per yard, and an axle-load of 5 tons, should be allowed, and named a "little railway." He would not follow the author as to what has been done in light railway-construction and working abroad, neither would he discuss the question of transshipment, as, in his opinion, the very fact of a railway being constructed as a light one meant that the traffic would be small, and therefore the inconvenience (if any) and the cost of transshipment would not be worth consideration. He preferred to deal with the financial aspect of the subject, and he must say that he was much disappointed with the manner in which this part of the question had been dealt with by engineers, who said that, comparing like with like, there was very little to be gained by narrowing the gauge. This was true. But in dealing with this subject we had not to compare like with like, we had to compare a light railway with a little railway. The permanent way of the latter would cost 50 per cent. less than the permanent way of the former, and other works of construction would also follow in the same proportion. If a standard-gauge railway has been constructed in one part of the country for £4,000 per mile, it does not follow that all standard-gauge railways in any part of the country can be built for the same figure. He had constructed a railway on this gauge for £1,000 per mile. But what kind of a line was it? It was made for a special purpose, of second-hand rails, and second-hand sleepers following the inequalities of the ground, and was altogether a temporary surface-line. In order to compare accurately the cost of railways on different gauges, each railway should pass through the same district and a separate alignment for each gauge should be estimated for, according to the curves and gradients previously decided upon for each gauge, and when this had been done the relative cost of the different types of railways could be determined. In India, an estimate for three different types of railway was prepared on this plan, with the following result for 17 miles of railway:—

Gauges.				Cost per Mile.	
Standard, 5 feet 6 inches	...	...	...	£2,927	
Metre...	...	...	...	£1,969	
2 feet 6 inches	...	...	...	£1,817	

A splendid example of the actual cost of railways on the 5 feet 6 inches gauge and metre gauge running through the same district is to be found on the Bengal and Nagpore Railway. This railway for 145 miles was laid on the metre gauge with rails weighing 40 lbs. per yard, and the original cost of the line was £6,000 per mile, without rolling-stock. When it became advisable to shorten the distance between Bombay and Calcutta, this portion of the line was converted to the standard gauge at an extra cost of £3,000 per mile, after allowing full value for the old materials removed from the metre-gauge line. Thus we see that a metre-gauge railway capable of carrying all the traffic of the district was constructed for the sum of £6,000 per mile, whereas the standard-gauge line built to carry the main-line rolling-stock, with its heavier permanent way, flatter curves, additional land, wide cuttings and embankments, cost £9,000 per mile; and this is not the actual extra cost, for a tunnel on the metre gauge was originally made large enough for a standard-gauge line. When we come to the question of working expenses, we are lamentably behind our Continental neighbours. In Ireland, the so-called light railways (they are not light railways but main lines in miniature), are worked at a cost of £3 10s. per mile per week (the lowest cost), whereas on the Continent these railways are worked at £2 per mile per week, giving a train service of three trains per day each way. To make light railways a success in this country, or in any country, we must rid them of the traditions, the management and the routine of the main lines, altogether too extravagant for them, and conduct them on lines similar to those on which the old coaching traffic was conducted before the advent of railways.

Lieut. E. LEGGETT (Woolwich Arsenal) congratulated The Federated Institution of Mining Engineers upon the selection of the subject of light railways for discussion, and upon their good fortune in having so able and interesting a paper upon that subject as that just read by Mr. Leslie Robinson. The subject had had a particular claim upon their attention since the days of the construction of the Stockton and Darlington railway on principles of strict economy, such as would now constitute a light railway. As Mr. Robinson had reminded the members, the cheapness of the railway, as such for the particular purpose for which it is built, determines its "lightness," and no question of gauge necessarily entered into

the matter. That line was built as a mineral railway; and though, since then, it and others have enlarged their scope, and consequently have had to adopt signals and all the complicated safety-appliances necessary where passenger traffic had to be provided for, yet there were to this day many miles of strictly light railways running all over the colliery districts in the North of England, and carrying an enormous mineral traffic, which were, in every sense of the word, "light railways." These lines cross and re-cross main roads, in many cases without the provision of gates, or over-bridges; and it is a remarkable fact, eloquent as to the care of those responsible for them, that accidents to life and limb, in consequence of such omissions, were practically unknown. The value of these lines to the collieries owning them was unquestionable, and he would suggest that enquiry as to their working expenses would afford valuable information.

The time for insisting upon the necessity of such means of cheap transport of a secondary nature is now past. Public opinion has been educated by such men as Mr. Robinson and Mr. Acworth, and we have now got an Act of Parliament which is liberally drawn, and, it would appear, is being liberally interpreted, by the Light Railway Commissioners. A large number of schemes have been submitted and provisionally approved, and their diversity of character in details is so great as to suggest the thought that some guiding spirit is very necessary to prevent error due to the free rein given to individual fancy. The mention of a suggested 3 feet 10 inches gauge railway is sufficient to show his (Mr. Leggett's) meaning. Such a line must be special in every sense. The locomotives, rolling-stock, and plant must be specially designed, and will, no doubt, be proportionately costly. However, in these respects one may rely upon the survival of the fittest, and as Mr. Robinson had said, this will, no doubt, resolve itself into the adoption of the 4 feet 8½ inches and 2 feet 6 inches gauge-standards, to suit the two sets of conditions he enumerated.

One other warning—it had too long been the general fallacy that a rail, a truck, and a locomotive thrown together make up a railway. When such a railway is found to be expensive to work, or the rolling-stock unsuitable to the traffic, or the locomotive too heavy for the rail or too light for the traffic—the damage is done, and such failures will react on light railway-enterprise and check the spread of what should become a great economic factor and stimulating agency throughout the trade of the country. The elements of the railway must be designed with reference to the traffic to be expected, which will be generally uniform in each case—such as minerals, agricultural produce, etc.—and again, these elements must be designed with reference to one another as

parts of a machine doing a given task. In this connexion, it is obvious that standardizing the rolling-stock and other plant as much as possible will aid powerfully in economizing on initial outlay and subsequent maintenance.

He (Mr. Leggett) might mention a case of a light mineral railway in Wales paying 6 per cent. on its capital, of which $1\frac{1}{2}$ per cent. may be attributed to the economical design of its rolling stock and the large proportion of the paying to the tare load hauled.

It had been said that a large number of small lines, independent of one another, must be essentially costly owing to the heavy incidence of fixed and management charges. Mr. A. J. Balfour, speaking in the House of Commons on Mr. Bryce's bill of 1895, expressed the hope—founded on his experience of Irish light lines—that it might be found possible to group several lines in the same county or locality under one management, and that this would enormously increase their chance of success. Belgian experience is in the same direction, and the point is worthy of all attention.

Finally, the relation of the small line to the trunk systems is a delicate matter, and Parliament had added to the difficulty of it by insisting from the first that the whole expense of junctions must be borne by the newcomer—in this case the light railway. This enactment we cannot hope to see altered except by strenuously working to show the main line company that the light line is its friend and feeder—not its competitor—and that to aid the feeder by mileage rebate or other means will develop a traffic which must eventually benefit the main railway, who will eventually be the larger gainer.

Mr. ERNEST BENEDICT (M. Inst. C.E., London) wrote that Mr. Robinson had made such excellent use of the opportunities offered to him at the last International Railway Congress, when the subject of his paper was discussed, that he had not left much to be said. He would suggest the designation "light" for lines of normal gauge on which the speed was restricted, as in the second and third class lines in some countries on the Continent; and the name "little" for lines of less than the normal gauge of 5 feet 6 inches in India, 3 feet 6 inches in Africa, and 4 feet $8\frac{1}{2}$ inches almost everywhere else. The Darjeeling-Himalayan and the Festiniog "little" lines, although of very narrow gauge, cannot be called "light;" and those "light" lines which take normal stock at reduced speeds cannot well be called "little" lines. He would like to ask Mr. Robinson why "gradients can be steeper" on light than on heavy lines? A good way of com-

paring the advantages and disadvantages of narrow and normal gauge lines is to enlarge the drawings of the former, and to reduce those of the latter, when the difference can be clearly seen and appreciated. Compare the 2 feet 6 inches gauge, say, with the 4 feet 8½ inches, and call the first (for the sake of example) just half the size of the second. Alter the scale of the drawings of the first from 3 to 6 inches to the foot, and those of the second from 6 to 3 inches to the foot, and then compare them with drawings, 6 and 3 inches to the foot respectively, of the other gauge. Mr. Calthrop's stock, which is about 8 feet wide on the 2 feet 6 inches gauge, would become nearly 16 feet wide on the normal gauge, and, on the other hand, the 8½ feet wide stock on the normal gauge would become something like 4 feet wide on the narrow gauge, and so on. It should be borne in mind that every *détour* made to avoid heavy work lengthens the line by a certain amount. This additional length adds not only to the initial expense, but to the cost of maintenance and of hauling for ever after, and this cost increases with the traffic. It had never yet been satisfactorily explained why railway contractors, as a rule, lay down their temporary lines with the normal gauge, instead of using the more handy narrow-gauge tracks and vehicles. Again, unless the narrow-gauge stock is made to carry as much per vehicle and per lineal foot of train as the normal stock, the number of wheels per ton hauled is increased, and the length of train per ton freight is also greater, necessitating in the one case comparatively greater hauling-power, etc., in the other longer siding-accommodation for the increased number of vehicles per ton moved. All these questions, together with that of transshipment, can be reduced to pounds, shillings, and pence; although in many instances the calculations could not be made except at the cost of infinite pains. But any engineer who proposes departing from the normal design of permanent way or of rolling stock should be able to give his reasons for such departure in pounds, shillings, and pence. There is no doubt that Mr. Calthrop, in making his axle-load uniform throughout, has hit upon one of the most important points to be considered, and one which, to his (Mr. Benedict's) mind, will entirely revolutionize the present practice. If it can possibly be avoided, it is of course ridiculous that the engine axle-loads should be double that of the rest of the stock.

Finally, the writer would recommend for roadways the reverting to plates on which all wheels could travel, including flanged wheels, which would come to no harm while running at slow speed on their flanges. Flanged wheels were adopted on tramways, where they are not needed, because they were used on railways where they were a necessity. They

were also introduced in order to keep the ordinary traffic off the tram-lines. Plate-roads would be a boon and a blessing to all draught animals and to all wheeled traffic, and, although expensive in the first instance, would soon pay for themselves by lightening the work to be done both by beasts in drawing their loads, and by man in maintaining the roads. He would suggest the use on plate-roads of T-shaped steel plates, $\frac{1}{4}$ inch thick, 10 inches wide, 6 inches deep, rolled in lengths of 60 feet, weighing from 80 to 100 pounds per lineal yard, and with a wavy top-table. The plates would be supported on longitudinal karri or jarrah timbers, shaped by machinery from 10 or 12 inches baulks, preferably vulcanized or creosoted, covered externally with hot pitch, and bolted together at intervals of 4 or 5 feet, or on castings. No cross-ties would be used, and ends of rails and timbers would always break joint.

Mr. ROBERT J. MONEY (Hull) wrote that he entirely agreed with Mr. Robinson's conclusions, but would emphasize the following principles and points. A "light railway" is not necessarily "a narrow-gauge" railway, but is one in which a slower speed and lighter rolling-stock are adopted; and therefore lighter rails, lighter bridges, and sharper curves are admissible. When the estimated traffic will not allow of a standard* gauge line, then, and not till then, should a narrow-gauge line be considered. The American method of construction in uninhabited districts, or where the traffic is light, is correct in principle and applicable to light railways in older countries. Briefly, it is to lay down the line as cheaply as possible, with sharp curves and steep gradients, so as to reduce the earthwork to a minimum; to put in temporary structures for bridges and culverts to be replaced by permanent ones after the road is completed; to erect only the cheapest possible structures for stations and buildings, so as to obtain a railway, earning on the smallest possible capital; and, as the traffic increases, to improve first the road-bed by good ballast and permanent structures over waterways, then the alignment, by reducing the gradients and increasing the radius of curves, and last of all permanent and ornamental buildings. In other words, they put their money into the permanent way and rolling-stock and refrain from spending on what is not absolutely necessary or ornamental, until they can do so out of revenue. No economy should be attempted in the rolling-stock or permanent way, the one must be suitably designed to meet the requirements of the other, and both must be maintained in a good state of repair. As an illustration, take the rough rule that "the weight of rail

* By standard is meant, the standard of the country in which the line is to be built or the standard of the system to which the light railway is a feeder.

in lbs. per linear yard should equal 12 times the greatest weight in tons on a wheel." If a 30 lbs. rail has been adopted, then the greatest weight on a wheel should not exceed $2\frac{1}{2}$ tons. Or if you know that an engine with 10 tons on an axle and therefore 5 tons on a wheel, is to run over the road, then you will require a rail of 60 lbs. per yard. Any infringement of this rule will manifest itself to the general manager in increased cost of maintenance; so also will unnecessarily sharp curves or steep gradients, and therefore in laying out a line, it is necessary to take into account the working of it, in order to obtain a financially successful railway. And here he desired to emphasize strongly the fact, that no expense should be spared on the surveying, which is one of the most important details of any railway scheme. One hundred pounds more spent on a survey may result in a saving in the cost of construction of from £1,000 to £10,000.

The Guatemala Central railroad is a good example of the American plan of construction and working. It runs from the port of San José, is 75 miles long, and crosses a summit of over 5,000 feet before arriving at the terminus in Guatemala city. Originally constructed with very sharp curves and steep gradients, it has developed so large a traffic that out of their earnings they have been able to considerably reduce the gradients and curves, in some places by a completely new alignment for several miles. There is at the present time a branch line under construction 25 miles long, which is being paid for entirely out of revenue. The line is worked for 45 per cent. of the gross receipts, and the principle adopted has been to put the money into the road bed and rolling stock, and except for the buildings at Guatemala city, an Englishman accustomed to the English style might consider their stations as only temporary structures.

As regards "break of gauge," this need not entail all the inconveniences sometimes suggested. For transshipment, the narrow-gauge line may be run alongside the standard-gauge line, so that the floors of the cars are on a level with each other, and loading and unloading easily and cheaply performed. In Italy, in some cases the narrow-gauge line utilizes the standard-gauge line stations by running into them over the existing track, a third rail being laid for the purpose. The saving thus effected in entering a large town, where land is expensive, is very considerable. As regards separate workshops, this would not be necessary if the narrow-gauge railways formed part of a large system, belonged to a large company, or worked in harmony with a big railway. The engine-drivers, who should be sufficiently good mechanics, would carry out all ordinary

repairs, and all large or extraordinary repairs would be effected by taking the locomotive to the workshops of the standard-gauge line. In Bavaria, the light railways form part of the system of state railways, and while of standard gauge, are worked under an entirely separate management, and give good results. In East Africa, the railway from the port of Beira to the Portuguese frontier, 212 miles long, is of 2 feet gauge, while the extension to Salisbury, in Mashonaland, of 156 miles, is to be the South African standard gauge of 3 feet 6 inches. After this line is completed, the narrow-gauge line will be converted into 3 feet 6 inches gauge. The existing 2 feet gauge will of course enormously facilitate the construction of the Salisbury extension-line. Had a wider gauge than 2 feet been insisted upon in the first instance, it is improbable that capital for its construction would have been found, while to-day the traffic has so increased that it is considered desirable to build the extension-line of standard gauge, and afterwards enlarge the 2 feet gauge line.

Mr. W. COCHRANE (Newcastle-upon-Tyne) said that no doubt light railways were adapted to a particular class of country where steam-motors would not be applicable, but it seemed to him that at the present moment, in Great Britain especially, with all our jealously guarded private rights, the extension of light railways was not likely to be of very serious moment, and the development of steam-motors seemed to him to be likely to render that of light railways unnecessary. To mention brick-yards as an instance, a motor could be taken into the yard for its load, which it would then deliver alongside the building where it was required; but in the case of a light railway it would be necessary to cart the bricks to the railway and then load them into trucks, tranship and then cart again. Therefore, while he did not want to depreciate what light railways could do under particular circumstances and the advantage they were, he did not think that they were likely to be adopted to any great extent if the steam-motor developed as it appeared likely to do.

The PRESIDENT proposed a vote of thanks to Mr. Robinson for his paper. Light railways had been stopped very much by the action of the Board of Trade, which imposed severe restrictions (if they required state aid) as to gate-keepers, crossings, and so on. They were probably better adapted for other purposes than for collieries, for colliery traffic alone would almost justify a heavy-gauge railway. Light railways would probably be cheaper and in some cases more advantageous than motor-cars, for while 20 tons would be difficult to move along an ordinary road by a motor-car, it did not present any such difficulty when placed on a railway.

Mr. A. L. STEAVENSON (Durham), in seconding the vote of thanks, remarked that if the railway was made without the assistance of landlords the parliamentary opposition alone would cost more than the cost given in the paper, and if half-a-dozen passengers were killed the cost would be enough to ruin the railway company.

The vote of thanks was adopted.

Mr. LESLIE S. ROBINSON, in acknowledging the vote of thanks, said that without wishing in any way to deprecate the utility of motor-cars, he thought that their sphere of usefulness was not identical with that of light railways. In answer to the argument advanced by Mr. Cochrane, "that the development of steam-motors seemed to him to be likely to render that of light railways unnecessary," he would point out that the restrictions until quite recently imposed on motor-cars in this country had not existed on the Continent, and that even under these favourable circumstances motor-cars had in no sense superseded light railways or even hindered their development on the Continent, and he did not see any likelihood of their being able to do so in this country. Lient. Leggett's remarks in reference to the immunity from accidents on the railways in the mineral districts were well calculated to meet the objection advanced as to the probable accidents on light railways and corroborate the experience gained abroad. They also show that fencing and crossing-gates are unnecessary. The one important point in his paper was, he thought, the question of the adoption of the standard gauge for light railways. The ordinary gauge of 4 feet 8½ inches should be adhered to if possible, but where it was departed from the Board of Trade or some recognized authority should insist upon the adoption of a standard narrow gauge for light lines, and then a great portion of the difficulties surrounding light railways would be overcome. At present there were proposals before the Light Railway Commissioners for the use of no less than five different gauges. He thought if they could not use the 4 feet 8½ inches gauge they had better go to something much narrower. A standard narrow gauge should be decided upon and rigorously adhered to; their rolling stock would then be standardized, intercommunication would be greatly facilitated, and many of the difficulties which had been met with in India would be surmounted.

Mr. A. DURY MITTON read the following paper on "An Underground Fire at Bridgewater Colliery":—

AN UNDERGROUND FIRE AT BRIDGEWATER COLLIERY.

By A. DURY MITTON.

On December 2nd, 1896, the writer was called to go to the Bridgewater colliery, one of the collieries belonging to the Bridgewater trustees. On arrival, he found that the top of No. 4 Pit (upcast shaft) was on fire : the erections, consisting of a pulley-wheel, with small head-gear, used for going down to repair this shaft. The pulley-wheel had fallen down the pit, and the timbers were burning. On looking down the shaft, nothing could be seen but one red glare of fire—the whole of the brickwork being red-hot for some considerable distance up the shaft.

At this colliery there are 2 downcast shafts, 12 feet in diameter, known as Nos. 1 and 2 shafts, sunk to the cannel mine, a depth of 1,671 feet (Fig. 2, Plate XXII.) ; the Hollins Field pit, 12 feet in diameter, is used as an upcast shaft, and is also sunk to the cannel mine, and is used in the ventilation of the bottom mines.

The coal is won by means of a level tunnel, driven out for 3,270 feet to the north, from the bottom of Nos. 1 and 2 pits, which cuts the doe, trencherbone, and cannel mines. These coal-seams are known as the bottom mines, and all of these mines are being worked and the coal drawn at Nos. 1 and 2 pits.

No. 3 pit (the downcast) and No. 4 pit (the upcast) are sunk to a depth of 933 feet, or a distance of 201 feet below the seven-feet mine, as shown in Fig. 2 (Plate XXII.). From the bottom of these shafts, a level tunnel is driven 1,590 feet long to the south, cutting the seven-feet, brassey, crumbouke, and bin mines respectively.

A main haulage-road from the point A upon the plan (Fig. 1, Plate XXII.) is driven down in the seven-feet mine, dipping at the rate of 1 in 4 to a distance of 2,400 feet. At 1,200 feet distance, and at the bottom of this main haulage-road, connexions are made with the crumbouke mine above, and levels driven out in the seven-feet mine, in which a large area of workings is opened out. The whole of this coal is drawn up this inclined plane by means of the endless-rope haulage system.

At the bottom of No. 4 pit, a connexion is made with the level tunnel, where a furnace is fixed, 12 feet long and 6 feet wide, with end

and side doors, fed by fresh air from the main tunnel. Above the furnace, at the point shown in the shaft (Fig 2, Plate XXII.), are two boiler flue-drifts, where four underground boilers discharge into the shaft, working at a pressure of 45 lbs. to the square inch—the distance from the boilers to the shaft being 60 feet. Just below the entrance of the furnace-drift, a steam pipe (6 inches in diameter) exhausted itself from the underground hauling-engine. The main return-airway from the seven-foot mine workings passed into the upcast shaft 201 feet above the furnace-drift. The brassey mine having been almost exhausted, very little air was passing into the shaft at this opening, 81 feet above the seven-foot mine, and the air in the crumbouke mine (which is being largely worked) passed into the shaft 40½ feet above the brassey mine. There was no means of getting to the bin mine mouthing, the coal of which had been largely worked out.

On December 1st (the day before the fire broke out), 95,000 cubic feet of air per minute was passing along the main tunnel to ventilate the seven-foot and crumbouke mine workings.

The mouthings into No. 4 pit from the bin, crumbouke, and brassey mines were of 9 inches brickwork, with a 10 feet wide archway about 7½ feet high. The mouthing into No. 4 pit from the seven-foot mine was 12 feet wide and 10 feet high, with 9 inches of brickwork around the shaft, the coal, in all cases as far as we could see, having been left close up behind the brickwork.

After inspecting the state of the upcast shaft upon the surface, the writer immediately went down No. 3 pit and along the main south tunnel and up the seven-foot mine return-airway, which rises 1 in 3½ to the north. Stoppings were immediately erected to check the air in the main return-airway, and stoppings were also erected down the bank in the main levels to turn the fresh air direct into the crumbouke mine, to, as far as possible, direct all the air of the pit by the crumbouke return-airways, so that it exhausted into the No. 4 shaft above the seat of the fire.

It was found that the fire was advancing at the rate of 60 feet in ½ hour down the seven-foot main return-airway, as shown in Figs. 1 and 2 (Plate XXII.), and had come out as far as the letter *B*, a distance of 135 feet.

There was in No. 3 pit a column of water-pipes 5 inches in diameter, and it was ascertained that a pressure of 402 lbs. to the square inch at the pit-bottom could be obtained from the water-reservoirs on the surface. A hose-pipe, 3 inches in diameter, was laid along the main tunnel and up

the main return-airway in the seven-foot mine, a distance of 1,740 feet, and an attack was made upon the fire, and, after considerably reducing the return air-current with temporary stoppings, the water immediately checked the downward progress of the fire.

Another line of similar hose-pipes was laid and the second hose-pipe soon got to work, and, by degrees, the fire was beaten back slowly foot by foot.

The difficulty that now presented itself was, how to check the progress of the fire at the rise side of the shafts? The whole of the goaf on the eastern side was ventilated by a scale of air, and a gas-tap was kept at the highest point *C*, where fire-damp was very often found coming off from the eastern side of the goaf. This point naturally caused great anxiety, and no time was lost in getting into the top of these workings. A road is shown from No. 2 pit (one of the deep pits) which was practically closed—having been stowed up, and a small pipe left in it for a scale of air. An opening was made into this road, but carbonic oxide gas was coming out so strongly that very slow progress was made.

The question of driving an opening from No. 3 pit into the seven-foot main road presented many difficulties, as, without any knowledge of the distance that the fire had ascended up the main return-airway, it was not thought advisable to make this connexion for the present, as by doing so a considerable amount of fresh air would have been passed on to the fire; and had there been much fire to the rise of No. 3 pit, the air would have had a tendency to drive the fire farther up the brow to where there might possibly have been an accumulation of gas, or have spread the fire farther into the workings.

The work of beating back the fire on the main return-airway with the hose-pipes proceeded satisfactorily for a few days; but owing to the intense heat, the fire had caused the roof-coal to fall heavily, which in this mine is generally of a good character, and stands in most of the roads. *

* The strata between the brassey and seven-foot mines are as follows :—

No.	Description of Strata.	Ft.	Ins.	No.	Description of Strata.	Ft.	Ins.
1	<i>Brassey Mine.</i> — COAL	2	10	10	Shelly rock	3	7
2	Warrant earth	4	0	11	Rocky flue	1	0
3	White earth	2	4	12	Shelly rock	1	0
4	White earth with iron bands	4	0	13	Soft flue metal	23	0
5	Grey flue	17	0	14	White earth	5	8
6	Warrant	1	0	<i>Seven-foot Mine.</i>			
7	Rocky warrant	3	0	15	COAL , "Roofers"	2	6
8	Shelly rock	5	9	16	COAL , "Bottoms"	5	0
9	Burr	1	9	Total			
				82 8			

Above this roof, there is a very inferior class of stone, and this commenced to fall to a great height, and the roof-coal being hot and buried in the falls, combustion set in and the fire had to be driven back over the top of this fallen *débris*, which was smouldering and giving off carbonic oxide gas.

The work was then commenced of clearing out this fallen *débris* as fast as possible—there being 10 feet wide and 6 feet thick of hot burnt metal to move—which afterwards left the road in a good state, after having got it securely timbered, and no fire was seen in the coal-sides.

The No. 4 pit, at the entrance to the seven-feet mine after a few days of fierce burning, began to fall in and give way; and the whole of the coal around the shaft at No. 4 pit was burning fiercely, and blowers of gas coming out through the brickwork into the shaft. A road was driven round in the coal behind No. 4 shaft, and an attack made upon the fire from behind. By this means, the fire was overcome to some extent, although at the point *D* where four roads meet, the falls had extended to a height of 45 feet, and the metals were on fire.

During this time it was decided to board across the whole of No. 2 pit (downcast shaft) just below the seven-feet mine entrance, and put the whole pressure of the ventilation on to the gases that were coming out from the fire, so as to force an entrance. By leaving a return-airway for the gases through this stopping in the shaft, an air-road was bratticed down the main return-airway which was found on fire—falls having taken place; but by means of water mixed with bi-carbonate of ammonium run into the water-pipes at the top of the shaft, we were able to ascertain the state of the mine at the point *C*, where fire-damp used to be found. Carbon monoxide gas was found, or one which gave the impression of carbon monoxide from the bright blue cap that it produced upon the flame of the lamps.

An entrance was then made from No. 3 pit, two doors being erected between the main return-airway and the pit, and two coal-places were driven, *HI* and *KF*, with the view of ascertaining how far the fire had proceeded along the three eastern levels shown in Fig. 1 (Plate XXII.), which were standing open before the fire took place.

Owing to the heavy falls that had taken place on the main return-airway between Nos. 3 and 4 pits, a complete stopping was effected, as the metals had become so hot that they ran together and formed into large clinkers. The two coal-places, *HI* and *KF*, were driven, 6 feet wide and $3\frac{1}{2}$ feet high, at the rate of 20 feet in 24 hours. Holings were occasionally made at the points shown, and a bore-hole was put through to ascertain the position in these levels.

It was greatly feared that the fire getting along these levels to the old goaf on the eastern side (a goaf which was well known to be very open) and the roof-coal having been largely left, if the fire should take an active hold, it would be very difficult to overcome, and might spread to a very large extent.

One Sunday night, the writer was informed that the coal in the crumbouke mine was on fire, and upon visiting the mouthing, he found the whole of the brickwork was so hot that one could hardly hold one's hand upon it, although the shaft was considerably reduced in temperature.

There was no connexion between the burning fire in the seven-foot mine and the crumbouke mine, the brickwork in the shaft being comparatively cool, and the only thing that could be imagined was that this coal had ignited sometime at the commencement of the fire and had been smouldering behind the brickwork. Fortunately this fire was discovered, by having careful and repeated examinations made at these mouthings, before it broke out into the main return-airway in the crumbouke mine. A coal place was then driven behind the brickwork and a pipe was taken down the No. 4 pit, and this fire was extinguished and gave no more trouble. From the experience of the crumbouke mine, the writer is led to think that for some time previously, the coal behind the brickwork opposite to the seven-foot mine mouthing had been on fire. It is surprising, considering the distance from the furnace to this point, that the coal should have become ignited, as on the evening before the fire was found, the main return-airway was examined and nothing was seen.

Upon continuing the driving of the two levels *HI* and *KF*, a road was at length driven down into the top level at the point *E*, and the level was cleared of *débris* back towards the main return-airway, as shown by the arrow, with the view of making a return-airway. A fire was soon discovered in this level, which was burning fiercely and extending into the coal-sides to a depth of 9 feet in some cases, which meant a very wide opening being made for its extinction. The level was continued right through into the main return-airway, separating the connexion between Nos. 3 and 4 pits.

Upon holing the bottom-level *KF* into the old eastern goaf at the point *F*, it was found free from fire; but, upon driving a coal-place to hole into the bottom eastern level, fire was found burning actively within 18 feet of the edge of the goaf, a discovery which naturally led us to believe that the fire had got into the goaf.

A place *FI* was then driven along the edge of the goaf, an endeavour was made to try and cut off these levels by means of water, and after a

long battle this object was accomplished. A place was also driven from the top coal-level along by the edge of the goaf.

By these means the fire was very largely extinguished, as it was found that it had not penetrated far into the goaf, owing to the black damp, and, so far as the writer could see, the fire had only made its way along the edge of the goaf.

A connexion was then obtained between these two coal-levels *FI* round the edge of the goaf, and an attack was made upon the middle and bottom eastern levels, which were both filled with raging fires from one end to the other, and obtaining their air from the main return-airway by the contraction of the heated strata; the fire having passed up into the strata to a great height.

When the attack was made with water heavy falls were caused, and progress was very slow, but having driven a road round and made a return for the air, matters became easier, and by putting 22 inches air pipes overhead we could work underneath with the water, the gases passing above our heads.

Up to the present it will be seen that the question of erecting stoppings (although, of course, opinions might differ) was impracticable, as at the junction *D*, opposite the No. 4 pit, the bottom eastern level, which had been made secure, had been opened out and timbered in a distance of 50 feet; but no further progress could be made, owing to the strong gases that came off and the intense heat which was coming off from the overlying strata.

It was, therefore, decided that, owing to the large amount of carbon monoxide gas that was being given off, it would be wiser, for fear of an accumulation and the chance of an explosion, to let this level act as an outlet into the shaft and make the attack from the far eastern side.

The middle eastern level at the point *G* on the main return-airway could not be reached. At the junction *D*, the roof had fallen to a height of 45 feet and a width of 32 feet.

Progress could only be made very slowly in clearing these levels coming back towards the shaft; but by perseverance the object was attained, and a series of four brick stoppings were erected, as shown in Fig. 2 (Plate XXII.), built right into the coal until all traces of cracks were lost and the floor was cut down into a good foundation and fore-set with a tight packing of sand.

Holes were left in the stoppings fitted with plugs, and it was almost impossible to stand at the last stopping that was erected, owing to the black-damp.

By these means, the two levels which had fire in them on the eastern side of the stoppings near the goaf-edge had been completely cleared out, and only heated strata left therein.

The temperatures of the stoppings at the time when they were erected were as high as 106° Fahr., but are now down to about 60° Fahr. ; and at any of the holes in the stoppings, by abstracting a plug ($\frac{1}{2}$ inch hole), a lamp is immediately extinguished.

A 14 feet brick arch has been put into the mouth of No. 4 pit, 6 bricks thick, and a 10 feet arch in the main return-airway has been joined into this arch on either side so as to make a secure piece of work ; and above this 14 feet arch, to a distance of about 26 feet to the roof, the whole has been packed solid.

It may be interesting to state that palladium chloride (Pd Cl_2), which, when dropped on to pieces of white blotting-paper, has a reddish colour, when held in carbon monoxide (CO) becomes a black compound called palladium carbonyl (Pd COCl_2).

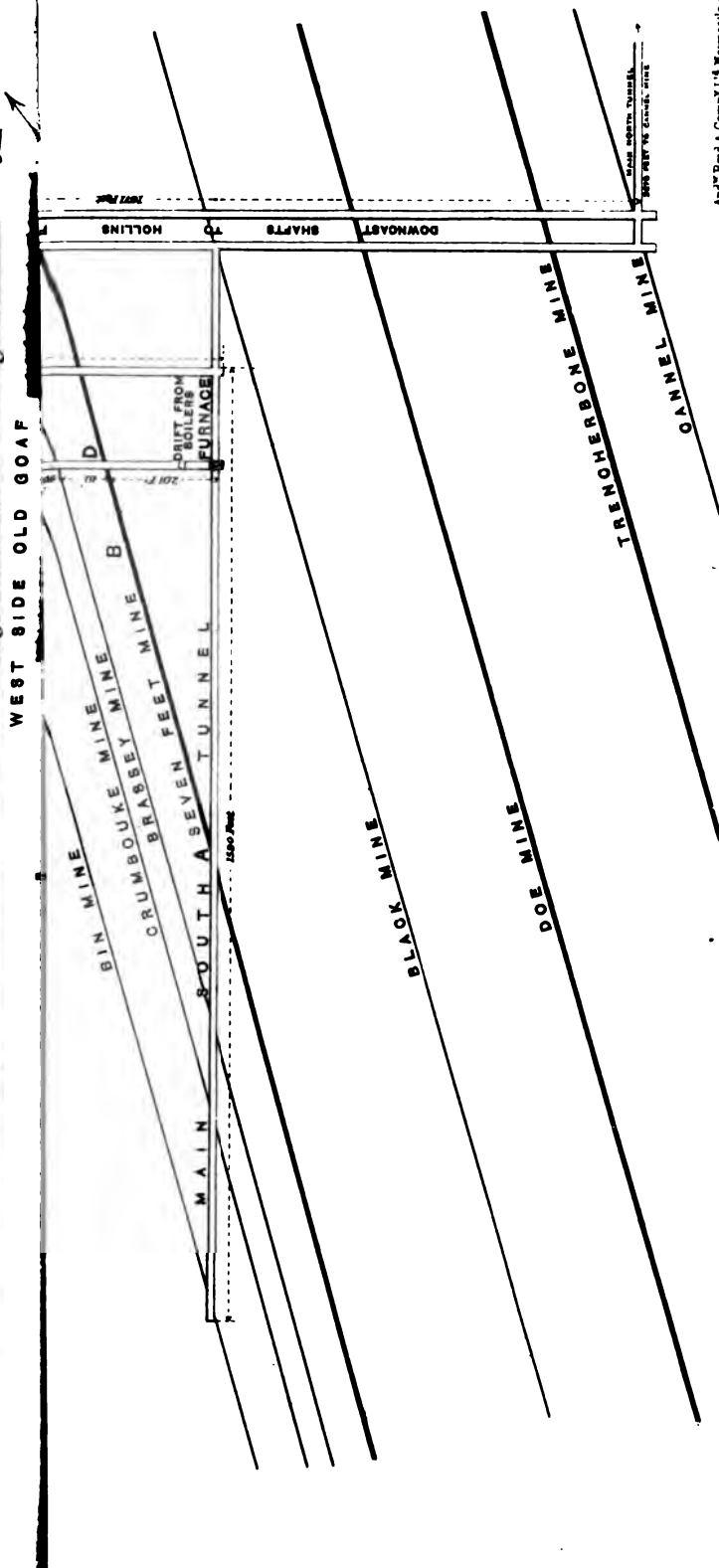
The writer made a few tests with palladium chloride and carbon monoxide in comparison with ordinary coal gas. It is difficult to distinguish between carbon monoxide and methane by the test of the cap of a lamp—the blue flames being much alike, and the exact percentage of carbon monoxide is difficult to ascertain. Owing to the deadly nature of carbon monoxide gas to workmen and its explosive tendency, it becomes of some importance in a case of this nature to obtain as much reliable information as possible.

With Clowes protector safety-lamp with hydrogen-flame, the writer easily obtained at places a cap 3 inches in height.

The use of palladium chloride forms a useful test for carbon monoxide by holding the blotting-paper in the mixture and ascertaining its proportions by the varying black colours that it produces. The comparisons of these tests with the gas in the pit as compared with ordinary coal gas containing about 6 per cent. of carbon monoxide is most interesting.

It may be interesting to state that during the clearing of one of the levels, by the men opening a large mass of fire and pouring on water at a great pressure an intense volume of gas was given off which ignited and continued burning with a blue flame for a length of 450 feet towards the shaft, up the top level (Fig. 1), and passed over some men, who threw themselves upon the ground without the flame doing any harm to them. This flame was met by two boys pushing in a tub which nearly filled the place, and was extinguished by the concussion at the point *E* (Fig. 1 Plate XXII.).

To illustrate Mr. A. Dury-Mitton's Description of An Underground Fire at Bridgewater Colliery."



And^w Rend & Comp^y L^d Newcastle on Tyne

The question of flooding the mines was fully discussed, and the points which presented themselves were these : if flooding had taken place, strong dams would have had to be erected at the points, Nos. 1, 2, 3, 4, 5, 6, 7, 8, and 9 (Fig. 1), and these dams would have had to stand a pressure of 192 lbs. per square inch, or up to the level of the brassey mine. This goaf would have been filled up to the line, shown on the plan (Fig. 1), before it would have covered the highest point where it was assumed that the fire existed.

Now, at the time, there was no doubt that the fire was increasing, and that the insertion of these dams in these particular mines would have required a very long time. The water would have had to be stopped by another strong dam, No. 9 in the main tunnel. There was then only left the distance of 40 feet from the brassey to the crumbouke mine, and it would have been impossible to prevent the water from passing down into the crumbouke and seven-feet mines to the dip, as at the south-western corner of the old workings the goaf was connected with the whole pit.

The writer is greatly indebted to the courtesy of Mr. Gerrard, H.M. Inspector of Mines, Mr. Maurice Deacon, and Mr. H. Woodward, for able advice tendered during a most tedious and trying time, which few people can understand except those who have witnessed an extensive underground fire.

Mr. A. L. STEAVENSON said that the operations described by Mr. Mitton had proved most successful, and very great credit was due to all concerned for carrying through a most dangerous operation. The only question was whether they were warranted in undertaking extinction of the fire, accompanied as it was, with such immense risk.

Mr. JOHN GERRARD (H.M. Inspector of Mines, Manchester) said that the members ought to be grateful to Mr. Mitton for placing on record for the benefit of his fellow mining engineers his very trying experiences. Mr. Mitton struggled with this fire daily, and had over 100 men employed on it for about three months, and the members would appreciate what a trying time it was. Mr. Mitton, as the members would gather from the paper, was at last able to shut off the air by putting in stoppings, and they would all hope that those stoppings would in time completely extinguish the fire. Having been with Mr. Mitton on many occasions

during the fire, he had in his mind two or three points which it might perhaps be worth while mentioning. One was that while the absolute necessity of shutting off all the air possible would be freely recognized, it was as absolutely necessary to have air in which the men could work. The difficulty was to so reduce the amount of air passing on to the burning material as to enable the men to work. That could only be dealt with by those in charge at the time, and in full view of the conditions and circumstances present.

Another point which came out very strongly in connexion with this fire was that the men were frequently under the influence of carbon monoxide, and the value of compressed oxygen as a remedial agent was proved over and over again. He (Mr. Gerrard) stood one night within a foot or two from a strong, active young man, not more than 21 years of age, the picture of health, who was holding a hose-pipe; he (Mr. Gerrard) walked away for about 15 feet, and heard a cry for him to return. The young man was stretched on the floor unconscious: as soon as the water had been turned off, the gas came upon him, and he was struck down as though with a hammer. It took two hours to bring him round, and he would probably have succumbed had it not been for the application of compressed oxygen.

Safety-lamps were used, owing to the occurrence of fire-damp, and from the blue cap they were not sure whether fire-damp or carbon monoxide was present. As it was most important that the latter gas should be recognized, if present, Mr. Mitton asked a chemist, "Do you know anything that can be used to ascertain whether this gas is fire-damp or carbon monoxide?" The chemist suggested the use of palladium chloride. This substance was used in solution, a few drops being placed on a piece of white blotting-paper, and the change from a delicate pink colour to a decidedly different shade showed the presence of carbon monoxide. Having taken great interest in Prof. Haldane's paper in regard to the blood tests, and the application of mice, he felt at the time that the use of palladium chloride was much better either than pricking their finger and drawing blood, or the introduction of mice. He sent some of these pieces of blotting-paper afterwards to Prof. Haldane, showing the traces of intense black produced by carbon monoxide, and that gentleman discounted the value of the test altogether, saying that it was not reliable, inasmuch as a similar result could be got from ordinary coal-gas. He (Mr. Gerrard) submitted to Prof. Haldane that having tried it in ordinary coal-gas, there was a decided difference in the results: that from coal-gas was not

so strongly pronounced, being only a light brown, as compared with the strong black produced by carbon monoxide. Prof. Haldane still maintained his opinion, and it was to be hoped that Mr. Mitton having brought the question forward, there would at any rate be some decisive pronouncement on that point.

Mr. R. A. S. REDMAYNE (Seaton Delaval, Northumberland) wrote that he was particularly interested in Mr. Mitton's interesting allusions to the presence and peculiarities of carbon monoxide. The question of the presence of carbon monoxide, as constituting the chief element of danger in the mine atmosphere after colliery explosions, had of late years occupied the attention of mining engineers. He did not think that the presence of this gas was a peculiarity of latterday colliery explosions, as in all probability the after-damp of the early colliery explosions was of a similar nature to that of later years; but, largely owing to the exhaustive investigations and admirable contributions to the mining literature of the subject of Messrs. W. Galloway, J. B. Atkinson, W. N. Atkinson, and others, attention had been more particularly drawn to it. Mr. John Buddle noted in his description of the Wallsend colliery explosion (1835) that "although the Davy's burnt very well, the after-damp was so strong that it overpowered them, and, but for the reserve . . . some of them would have been lost."* Mr. Mitton remarked on the deadly nature of carbon monoxide and its explosive tendency, but the latter peculiarity would not adversely affect an exploring party, for although the presence of $\frac{1}{2}$ per cent. of this gas in the atmosphere would render it fatal to human life, such an atmosphere would be a long way short of an explosive mixture (containing about 33 per cent.). Mr. Mitton mentioned the fact that with a Clowes protector safety-lamp with hydrogen flame he easily obtained at places a cap 3 inches in height. What percentage of carbonic oxide would this represent as present in the atmosphere? And what proof had he that the cap demonstrated the presence of carbon monoxide, seeing that the cap was of similar character to that which one would expect from the presence of fire-damp? That a cap 3 inches in height was procurable in an atmosphere containing under $\frac{1}{2}$ per cent. of carbon monoxide was difficult of credence. He did not know how the relation of percentage of gas to height of cap compared in the case of these two gases (carbon monoxide and fire-damp), but in some experiments made with an Ashworth-Clowes hydrogen-lamp in the return-airways of a fiery colliery

* *Trans. of the Natural History Society of Northumberland and Durham*, vol. ii., page 359.

some years ago by Mr. Walton Brown and himself, it was found that the highest cap was 2·8 inches of the scale, which showed the presence of more than $3\frac{1}{4}$ per cent. of fire-damp in the air. If the proportion be the same with carbon monoxide, Mr. Mitton's cap would demonstrate the presence of over 3 per cent. of that gas. The experiments of Dr. Wm. Murray of Newcastle, made in conjunction with the late Professor Freire-Marreco of the Durham College of Science, conclusively proved that $\frac{1}{2}$ per cent. of carbon monoxide was almost instantaneously fatal to mice placed in a vessel the atmosphere of which contained such a quantity of this gas, whereas he believed about 5 per cent. of carbon dioxide was necessary to produce similar results.

The subject was a peculiarly interesting one, in view of the recent Snae Fell mine disaster in the Isle of Man, and similar instances to that described by Mr. Mitton.

Such papers as Mr. Mitton's, detailing (as it did) the measures taken to combat the extension of, and dangers accompanying, such accidents, and coming direct from those who have had the control; both for the account and for the discussion to which they give rise, were valuable as records and for reference.

Mr. HERBERT W. HUGHES (Dudley) wrote that a most curious event happened a fortnight ago. Some roadways in a mine now working were connected into the roadways of a colliery which had ceased working about 50 years ago and whose shafts had been covered over with iron plates on which turf had grown. In less than 24 hours after the connexion had been made the roadways of the old mine were on fire from end to end.

The PRESIDENT proposed, and Mr. W. COCHRANE seconded, a vote of thanks to Mr. Mitton for his interesting paper.

Mr. A. D. MITTON, in acknowledging the vote of thanks, said with regard to Mr. Gerrard's remark about the stoppings there was little doubt as to the fire being absolutely extinguished at the goaf edge, as the temperature of the mine was normal, and the black-damp behind the stopping issued very strongly from the goaf when the plug was extracted. He agreed with Prof. Haldane's answer to Mr. Gerrard that coal gas would give the same result as carbon monoxide when the palladium chloride test is applied, as coal-gas invariably contained 6 per cent. of carbon monoxide. He believed that palladium chloride would indicate by change of colour from 0·05 per cent. and upwards of carbon monoxide. With the smaller percentages of gas pink and reddish tinges were obtained; with the larger quantities dark brown, grey, and black were given. It might,

therefore, be possible by making standard mixtures of carbon monoxide with air, and testing them with palladium chloride, to arrange a corresponding scale of densities of colour to know the actual percentages of carbon monoxide. If Mr. Redmayne refers to Dr. F. Clowes' book on the *Detection and Measurement of Inflammable Gas and Vapour in the Air* (page 57) he will find a scale showing the percentages of fire-damp for every inch cap upon the hydrogen flame. He (Mr. Mitton) assumed that the cap of 3 inches that he obtained upon his lamp was carbon monoxide owing to its very dark blue colour, and the black palladium chloride test he had made, in comparison to the flame of methane, which is of a slightly purple or much lighter blue colour.

The following paper by Mr. H. Foster Bain on "Machine Coal-mining in Iowa, U.S.A.," was read :—

MACHINE COAL-MINING IN IOWA, U.S.A.

By H. FOSTER BAIN, ASSISTANT STATE GEOLOGIST.

It may be safely asserted that machine-mining as applied to the Iowa coal-fields is already at many points a technical and financial success. Experimental work is still being carried on, and it may be expected that machines of greater economy as well as of a greater range of applicability will be in time developed. The types now in operation have nevertheless proved their fitness to meet certain of the conditions of the coal-seams, and where the latter are not unfavourable they yield a very comfortable margin of profit to the operator and greatly increase the ultimate economy of the mining. They cannot, however, be used to advantage in every mine, since the conditions are not the same in all parts of the field, neither is the economy always the same. A change in the mining rate may at any time convert the balance of profit into loss and *vice versa*.

In recent years, the price of coal in Iowa has been steadily falling. New mines have been opened faster than the trade has grown, and new railways have brought eastern coal into competition with the local product. The mining rate has been going down with the selling price, but not with the same relative rapidity, and as a net result the operators have been forced to face a steadily decreasing margin of profit. Under these circumstances, several of the larger companies have begun to investigate coal-cutting machinery, and it is expected that a number of mines which have heretofore depended upon manual labour will shortly be equipped with machines.

Many of the earlier forms of coal-cutting machines were tried in Iowa mines. The old Styne-Smith was experimented with in the mines of the Crescent Coal Company at What Cheer; one of the earlier types of the Mitchell machine was used for a while in the Forbush mine of the Whitebreast Fuel Company; and some of the earlier forms of the Harrison machine were employed at Angus.

The machines which are now most largely used, the Harrison and the Legg, are of the older types, and lack many of the more recent improve-

ments. For example, the Legg machine, the patents on which were later absorbed by the Jeffrey Manufacturing Company, is not now manufactured since that company finds its more recently perfected chain-breast machine so much more efficient as to supersede the cutter-bar altogether. To a certain extent, this statement is also true of the Harrison machine; the ones now manufactured being much more perfect and much more economical than the older type. In view of these facts, the showing made by the machines is all the more noteworthy.

The Coal-measures in Iowa underlie about 20,000 square miles. As may be readily imagined, there is considerable variation in the conditions of mining, and in the introduction of machines, as in every other change in mining processes, these conditions must be carefully considered. In general the coal-field is a region of slight relief. The rocks are undisturbed and the coal-seams lie approximately flat. They however show some variation from the horizontal, being crossed by a few low rolls. They are also subject to pinches and occasional small faults. The mines are not deep and there is no gas to contend with.

The most serious limit to extensive mining lies in the fact that, with some exceptions, the coal-beds have no great lateral extent. In most instances the beds show rapid variation in thickness when traced horizontally, and the thick coal lies in a series of half-connected basins or pockets with intervening areas of thinner coal. In some instances the coal varies from 6, 9, or 10 feet down to 2 feet or less within 100 feet or so. In certain cases, the coal thins out and is replaced by slate. The thick coal is very irregularly distributed, and it is difficult to satisfactorily plan a mine which shall operate in it alone. This irregular distribution of the coal increases the expense both of prospecting and mining, and limits the life of a mine so that it is often, paradoxical as it may seem, cheaper to mine by more expensive processes provided the latter require the less expensive plant. The coal is in no case what would be called thick. Though seams as much as 13 feet in thickness have been mined, and 6 and 7 feet of coal is rather common, the average for the state would probably be between 4 and 5 feet. In view of these facts, it is not surprising that the mines are usually worked upon scant capital and the extra investment necessary for the introduction of machines is not often forthcoming.

As has been suggested, the mining conditions must control in the selection of mining machines. One of the most potent factors is the physical character of the coal as well as that of the roof and floor. The Iowa coals are bituminous, in the main non-coking, and rarely of block

form. They show horizontal lamination, and are hard-cutting. Sulphur balls are quite common, and clay-ironstone bands and "boulders" are not infrequent. These masses lie frequently in the slate above the coal, and complicate the problem of holding the roof. The latter is usually a soft slate or bituminous shale, at times with 6 to 14 inches of clod, black bat, or similar material, immediately above the coal. This material falls easily, and in most instances it is impracticable to hold an unsupported roof any considerable distance back from the face.

The coal is largely mined by blasting from the solid, comparatively little cutting is done, and much powder is used. When coal is undercut by machine and has had the sides sheared down it requires very little powder to bring it down, and hence a roof which would not stand the heavy shock of a full powder charge may be worked by machines. In blasting from the solid, the shots often cut up into the slate, and the rooms are frequently lost before they are driven their full length. In the What Cheer region it takes less than one-half the powder that is used in hand work to bring down the machine-cut coal.

In the southern part of the state, and running over into the neighbouring portion of Missouri, is a coal-field underlain by the Mystic coal-seam, which has been mined at several points by machines. This coal is in many important respects exceptional, as compared with the major portion of the beds worked in the two states. Physically, it is a soft though brittle black coal, breaking with a clean conchoidal fracture, and presenting a bright lustrous surface, much resembling anthracite. Its cleanness and the readiness with which it is handled and fires makes it a favourite for domestic purposes. It will not, however, stand rough handling or stacking, and for steaming purposes is rarely so good as the lower coals worked in other parts of the state. The peculiar physical characteristics mark it wherever mined, and its uniformity in this regard is a striking feature when it is compared with other Iowa or Missouri coals. Structurally, the Mystic region is as simple and uniform as could be desired. A few broad, low anticlinals, an occasional fault of a few inches and one of 50 feet, certain pre-glacial erosion-channels, and an occasional stretch of bad roof, are all that interfere with the most extended mining. The bed is not thick, but its excellent quality, wide continuity, and the ease with which it may be worked have led to the opening of a large number of mines. In Appanoose county alone there are now more than 50 shipping mines, besides a large number which supply the local trade. The total Iowa output from this seam for the year ending June 30th, 1895, was 395,700 tons. In 1898, it was 697,896 tons.

A detailed section of the beds found at Mystic is:—

No.	Description of Strata.	Ft.	Ins.
10.	Drift	12	0
9.	Limestone, heavily bedded, gray, fossiliferous ...	2	10
8.	Shale, bituminous, fissile	1	0
7.	COAL	1	6
6.	Clay parting	0	2
5.	COAL, with some pyrites near base	1	0
4.	Fire-clay	1	6
3.	Limestone, heavily bedded, fossiliferous	2	10
2.	Shale, gray clayey	11	0
1.	Shale, blue, clayey (exposed to water-level) ...	4	0

In the Iowa mines, most of the work is by the room-and-pillar system. Double entries are driven with cross-entries at intervals of 300 to 400 feet. From the latter, rooms are driven until they meet; the pillars are then mined back to the cross entry and the room entry walled up. The plan varies in detail with the character and thickness of the coal and the nature of the roof and floor. In a few mines, particularly in the case of thin beds, the workings are on the longwall system, and in the Mystic field there are some semi-longwall workings in which stub-pillars are left to protect the roadways.

There are three general classes of coal-cutting machines upon the western market: (1) machines designed solely for narrow work; (2) machines which may be used for both shearing and undercutting; and (3) machines which undercut only. The latter are of three types: (a) the chain-breast, (b) the cutter-bar, and (c) longwall machines.

Of the machines designed for use in narrow work alone, the Stanley-header is the best-known, and the only one employed in the Iowa mines. Two of these, of the unimproved types, and having no mechanical loader, were employed for some time in the Forbush mine of the Whitebreast Fuel Company. With air at a pressure of 60 pounds per square inch and three men to the machine (a runner and front and rear loaders), advancement of about 10 feet per working day was made in the Mystic coal-seam. This represented a fair average of the work done. The entry was left in good condition, there was only a moderate waste in the coal, and very light charges of powder only were used to bring it down. The superintendent was well satisfied with the result, but a change to longwall working did away with the necessity for the machine.

The machines of the second class are of the type known as the pick-machine. The Harrison, Yock, and Ingersoll-Sergeant machines, recently described by Mr. W. Blackmore,* are of this type. Of these, the Harrison machine only has so far been used in Iowa. About 30 machines, formerly known as heavy standard, are used by the What Cheer Coal

Company. The Walnut Block Coal Company, Centerville, also use this machine for shearing the Mystic coal-seam in three of their mines. They weigh about 700 lbs., and when mounted on 16 inches wheels are about 22 inches high. The machine is essentially a pick or percussion-drill, fastened to a piston, and driven by compressed air. The air is cut off at less than half the piston-stroke by means of an ingenious valve-motor, which is a small cam rotary engine, and is entirely independent of the piston motion. The machine delivers from 200 to 210 blows per minute. The recoil of the pick against the rear cylinder-head is in part received by leather cushions, which are supported by air cushions, and in part spends itself in forcing the machine up an inclined platform upon which it operates. In operation, the machine is mounted on a platform, as shown in Fig. 1, and allowed to run forward, working in under the coal. The cut is

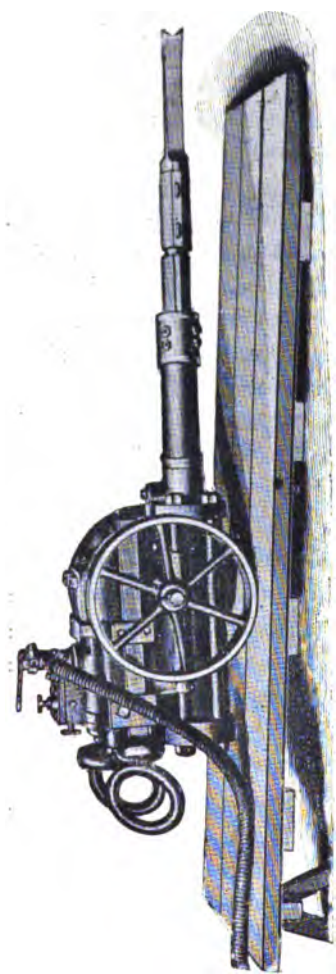


FIG. 1.—HARRISON MINING MACHINE: HEAVY STANDARD, CLASS B.—Manufactured by Mr. George D. Whitcombe, Chicago.

<-shaped in perpendicular cross-section, and may be made to vary in size to suit the condition. In many cases, it is a distinct advantage to give the cut considerable height in front, as this removes the necessity for wedging off the lower portion so as to make the coal roll out when blasted. The operator cares for the machine, while the assistant shovels

* *Trans. Fed. Inst.*, vol. xi., page 179.

back the dirt and arranges the platforms so as to keep the machine working along the face. In shearing, higher wheels are used, and a perpendicular cut is made across the bed. The change to the higher wheels takes only a few minutes.

The air-pressure is 75 lbs. per square inch in the later machines, but was kept lower in earlier forms. In the What Cheer mines, the air-pressure is 60 lbs. In all the Iowa mines, the Norwalk air-compressor is used. This compressor is of compound type, the air being compressed in two stages and passes through water-coolers on its way from the intake-cylinder to the compressing-cylinder. The compressor commonly used in Iowa mines has a 20 inches stroke with an air-cylinder 20 inches in diameter, compressing-cylinder $13\frac{1}{2}$ inches in diameter, and a steam-cylinder 20 inches in diameter. At 125 revolutions per minute, this compressor has a capacity of 909 cubic feet, the steam-pipe having a diameter of 4 inches, exhaust-pipe 5 inches, and water-pipe $1\frac{1}{2}$ inches. It requires 180 horse-power. One air-compressor of this size, at its full capacity, will furnish air for 10 machines. A plant of this character, including machines and air-compressor, costs at present prices about £1,200, to which should be added freight, pipe, and necessary steam plant. The capacity will of course vary with the character and thickness of the coal. In Illinois, the average production of the Harrison machine is given by Mr. Alexander Dick* as about 62 tons per day in seams varying from 6 to 7 feet in thickness. In the Iowa coal-field, the yield would usually be less—probably about 50 tons.

So far, but one successful electrical pick-machine has been introduced. This is the Morgan-Gardner, which has not been used in Iowa, but is in use in the neighbouring state of Illinois. In general appearance, size, weight, and mode of operation this machine is in all essential particulars similar to the Harrison and others of that class. The piston is actuated by a spring, which has a force of 1,400 lbs., and which is drawn back by a cam driven by a motor. The armature of the latter is of the toothed-gramme type, with coils wound below the surface. There are no wire connexions between the commutator and the coils, and hence the machine is much more durable. The recoil is as usual received in part by an air-cushion, and is in part expended on a gravity-plane. It is claimed that these machines can be driven at an expenditure of $8\frac{1}{2}$ horse-power each. In equipments, an allowance of 5 horse-power is made for each machine. In one Illinois mine, they are used for making a shearing-cut in a 9 feet

* *The Mineral Industry*, 1893, vol. ii., page 231.

coal-seam, cutting in $4\frac{1}{2}$ feet, and making four cuts per day. In this case, the cut is made in the middle of the room-face, and the coal is blown in from the sides without undercutting. The machine has not yet come into very wide use, but seems to have many points of excellence.



FIG. 2.—CUTTER-BAR MACHINE: LEGG TYPE, JEFFREY STANDARD, STYLE 2.—Jeffrey Manufacturing Company, Columbus, Ohio.



FIG. 3.—CHAIN-BREAST MACHINE: INDEPENDENT.—Link-belt Manufacturing Company, Chicago.

Undercutting-machines are being more and more widely used. Of the two forms which are adapted to both room-and-pillar and longwall work, the cutter-bar is the earlier, and the chain-breast is now the more popular. Both machines may be driven by either air or electricity. In the Walnut Block mines, cutter-bar machines of the Legg or Jeffrey types are used, driven by air (Fig. 2). The cutter-bar is armed with teeth

which are set so as to cover the whole face. This bar revolves forward and downward, and is at the same time fed forward. In these mines it cuts a kerf $5\frac{1}{2}$ inches high in the fire-clay below the coal, though it may be made to cut in the coal if thought desirable. With a cutter-bar $3\frac{1}{2}$ feet long, a 4 feet 8 inches cut is made in the fire-clay below the Mystic coal in about 10 minutes. This machine cannot dodge pyrites or other obstructions, but must grind them up.

The chain-breast machine is in many respects similar to the cutting-bar. It however has important advantages in that it attacks the coal from the side of the laminae, as may be readily understood from an examination of the illustration (Fig. 3). In this way, it gains greater cutting power and is to some extent relieved from cutting the sulphur balls. When the latter are not too large they are often raked out whole.

There are three machines of this type: they are the Jeffrey, manufactured by the Jeffrey Manufacturing Company, of Columbus, Ohio; the Independent, controlled by the Link-belt Manufacturing Company, of Chicago; and the Morgan-Gardner. Of these the Jeffrey and the Independent have been used in Iowa mines with electricity for power. Both the chain-breast and the cutter-bar machines have greater undercutting power than pick-machines, but they labour under the important disadvantages that they require more power and are heavier, 2,400 to 3,000 lbs., and hence are expensive to move from room to room. They also require considerable space at the working-face. In general terms, this should be 5 feet more than the length of the undercut, but in practice a few extra feet of space is often necessary and always a distinct advantage. The undercut is made in from 3 to 6 minutes, depending on its width and depth. A $5\frac{1}{2}$ feet undercut, 39 inches wide, and 4 inches high, is made with the Jeffrey machine in 4 minutes. The machines are naturally more expensive than the pick-machine. An equipment of three Jeffrey machines, two electric drills, 120 horse-power generator, 160 horse-power engine, and connexions was recently erected for about £1,200 and freight. A plant capable of mining 1,000 tons in 10 hours should cost about £2,000 and freight; the amount depending upon character and style of engine, generator, etc.

Longwall machines have not been much used in Iowa. In general, the successful longwall machines have worked on the principle of a bar or arm projecting under the coal and moved forward parallel to the face. One of the earlier Mitchell machines was dragged forward by the winding

of a rope attached to a point some distance ahead. The Link-belt Manufacturing Company now make a machine which feeds itself forward along a toothed rail braced against the roof and floor. In this case, the cutting is done by a chain similar to that used on the chain-breast machine, and running around the end of the projecting arm.

The Peerless Coal Company, of Centerville, Iowa, have perfected a machine for work in their mine which is self-propelling, and in which the cutting is done by a spiral band of teeth wound around the projecting arm and driven at high speed. This machine has not yet been put on the market, but is giving great satisfaction in a mine at Mystic.

The different types of machines are not applicable in all parts of the field. At What Cheer mine, where the coal is hard and does not "block" out, the pick-machine is the best. The improved cutter-bar and the chain-breast machines have not been tried in the coal, but the earlier forms did not prove a success, and the necessity for shearing makes it probable that the system adopted by the What Cheer Coal Company is still the best.

Mr. E. M. Trescott, general superintendent of the company, supplies the following estimate as to the cost of working with the Harrison machine. The machines have been used both in entry-driving and in room-work. The entries are driven 7 to 8 feet wide and $5\frac{1}{2}$ feet from bottom of rail to roof. In most of the entries it is necessary, in order to make that height, to either take up the bottom, or shoot down the roof and timber the roadway. The former plan is preferred, as yielding better and more easily maintained roadways. The cost of lifting the bottom, 15 inches thick (in a $4\frac{1}{2}$ feet coal-seam), is 4s. per yard in favour of machine work, to which should be added the coal saved, 2 tons, which makes a total saving of 8s. per yard in a $4\frac{1}{2}$ feet vein in favour of machines. In this work the machines are made to cut $4\frac{1}{2}$ feet, and three cuts is considered a good day's work. The men often, however, make $5\frac{1}{2}$ feet at a cut, and four or even more cuts a day.

When the men are paid by the day in machine-work the prices are: machine-men, 10s. 5d. (\$2.50); helper, 8s. 4d. (\$2); loader, usually 8s. 4d. (\$2); but occasionally 9s. 5d. (\$2.25). When the entries are driven all in slate, fire-clay, dirt, or anything but coal or rock, the contract price is 11s. 5d. (\$2.74) per yard; whereas the cost of hand-labour is usually nearer £1 1s. (\$5) per yard.

In some room-work, the undercutting has been paid for by the lineal foot, in which case the price is $4\frac{1}{2}$ d. (9 cents) per foot for a $4\frac{1}{2}$ feet

undercut, with $2\frac{1}{2}$ d. (5 cents) additional for the cost of shooting; loading and setting timbers is 1s. 8d. (40 cents) per ton of 2,000 lbs.

On an average, the cost of coal from machine-rooms is about 5d. (10 cents) per ton less than hand-mined coal, the district price for the latter being 2s. 1d. (50 cents) per ton, gross weight. In narrow work, on a basis of 7s. 6d. (\$1.80) per yard for hand-work, there is a saving of about 8s. 4d. (\$2) per yard, including the coal. Against this saving must be set the cost of maintenance of plant, depreciation, interest, etc. The cost of repairs for Harrison machines is slight, but in the end the main saving here seems to be in the recovery of a large amount of coal which would be inevitably lost by the ordinary methods of mining.

The Mystic coal is mined at Centerville by a combination of the cutter-bar machine for undercutting and the pick-machine for shearing. In room-and-pillar work in this coal-field, as carried on in most of the mines by hand-labour, the cross-entries are driven 300 feet apart; the pillars along the main roadways are usually 24 feet thick; the entries are 8 feet wide, and taken from cap rock to bottom rock; and the rooms are 150 feet long, and from 40 to 50 feet wide. In 1895, the scale of prices was as follows:—

				Summer, to October 1st.		Winter, after October 1st.	
				s.	d.	s.	d.
				Dollars.		Dollars.	
Room-work—							
Coal (screened)	...	...	...	2	11	0	70
Narrow work—							
Yardage	...	...	...	4	2½	1	01
Lifting bottom and shooting						5	0
down top	...	...	...	3	9	4	2
Coal per ton	...	...	...	2	11	3	4

At these prices, a yard of entry work in summer costs about 14s. 7d. (\$3.50), and in winter 16s. 8d. (\$3.80).

In working with machines as carried on in three of the mines of the Centerville Block Coal Company, the entries are driven 10 feet wide, and the cross-entries are run at a distance of 400 feet. Legg and Harrison machines are used mainly in driving entries and turning rooms, and but little room-work proper is done by them. In driving entries and turning rooms, the Legg machine does the undercutting, and is followed by a Harrison, which cuts the corners. The coal is then wedged down.

The Legg machines have a $3\frac{1}{2}$ feet bar, and are supposed to make a 5 feet cut. The average cut in actual work is 4 feet 8 inches. Three cuts are made to an entry, each taking about 10 minutes. The undercut is made $5\frac{1}{2}$ inches high. Two men are employed at each machine.

As soon as the undercutting is done at one point the machine moves on to the next, and is followed by a Harrison machine, which cuts out the corners. The Harrison machine requires two men, a runner at 9s. 7d. (\$2.30) per day and a helper at 6s. 8d. (\$1.60). The machine is expected to cut 16 corners, equal to 8 entry-cuts per day, which makes them cost 2s. (48 cents) each. Very frequently, however, as many as 21 cuts are made, which would reduce the average cost to about the figures given below. Measurements of the length of these cuts were 52½, 61, and 52 inches each. In shearing, a cut of about 4 inches in width is made.

One cut or rib furnishes about 3 tons of coal and 3 cars of dirt. The dirt is hoisted and dumped in narrow work, but in room-work it is usually gobbed. In narrow work, the two machines will make 8 to 10 entry-cuts per day of 10 hours, and keep from 4 to 6 followers busy. In wide work, there are 12 undercuts to a room, they make about 30 cuts per day, and keep 8 to 10 followers busy. A 4 feet 8 inches cut in a 10 feet entry ready for track costs about as follows :—

	s	d.	Dollars.
Undercut	1	0	0.24
Shearing	1	6½	0.37
Coal, 3 tons, at 34 cents	4	3	1.02
Brushing top	3	6	0.84
Total	10	3½	2.47

In comparing these figures with hand-labour it must be remembered that a machine cut is 48 inches and a hand cut is 36 inches, and on the other hand, the machines must bear the cost of repairs, depreciation, interest, etc.

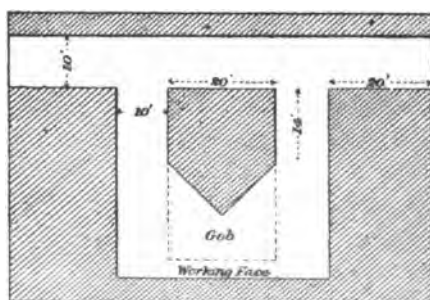


FIG. 4.—ROOM-AND-PILLAR WORKING IN MYSTIC COAL-SEAM.

In turning rooms, the two 10 feet doors are driven in 14 feet, and then opened out as shown in Fig. 4. The room is then turned over to the miners who drive it forward by undercutting, shearing, and wedging till the room from the opposite cross entry is met. The rooms are then left till that portion of the mine is about to be abandoned, when the pillars

are pulled. By that time, usually two years or more, much of the coal is not worth saving.

The major portion of the Iowa coal is like that mined at What Cheer rather than at Mystic, and at certain points at least is not suitable for mining with chain-breast machines. In the mines of the Carbondale Fuel Company, Des Moines, the machines were tried, but have been taken out. The fault was not in the undercutting, which was readily accomplished, but in the difficulty incurred in getting out the coal. The blast caused the coal to simply drop down and fill up the space cut by the machine. The spaces between the horizontal laminae seemed to expand so that the kirving (kerf) was closed, and it was almost as difficult to get the coal out as if it had not been undercut. In other mines where this trouble has been met with it has been overcome by wedging off the lower portion of the coal before shooting, but even this failed in the case in hand. This difficulty is quite frequently encountered when machines are introduced, and while it may usually be overcome by properly placing the blasts, there is a considerable amount of coal which probably cannot be profitably taken out without shearing.

At Oskaloosa, a coal is worked which, in general character, is much like that mined at What Cheer and at Des Moines. In 1895, Messrs. Long Brothers introduced into their mine one of the Independent machines, and it gave excellent results so long as the mine remained in operation.

These diverse results emphasize the fact that the mining machines so far introduced do not cover the whole field. In this state, as elsewhere, they are economical where the conditions are favourable, but new machines and modifications of old ones must be perfected before hand-mining loses its present supremacy. It is interesting to know that the work of experimentation is going on and that better machines are promised for the future*. With them and with the wider introduction of the present types will come reorganization of labour, greater efficiency, and greater economy.

Mr. W. BLAKEMORE (Glace Bay, Cape Breton) wrote that he had been much interested in Mr. Bain's paper and agreed with most of his conclusions. He thought that it might be taken for granted that the revolving cutter-bar machine had seen its day, and was now superseded

* *Colliery Engineer*, 1897, vol. xvii., page 313.

by chain-gear, which was much speedier in operation, required less power, and was more easily repaired when out of order. The coal-seams of Iowa evidently resembled those of Cape Breton in physical character and general condition, showing horizontal lamination, and being hard cutting, and also in containing numerous sulphur balls. These latter were the *bête noire* of the machine, as they were apt to break the teeth of the cutting-chain—in fact, there was no form of machine that was proof against them. He had seen one such ball strip the cutters from the Stanley heading-machine in a single revolution, and break at least a dozen teeth in the chain of a Jeffrey or a Mitchell longwall machine, and consequently he had adopted the use of percussion-machines exclusively in seams of this character. With the latter, the intelligence of the workman could direct every blow, the slightest twist of the handles at the rear would cause a corresponding deflection of the pick; in this way the operator could cut all around the obstruction and finally remove it without having seriously damaged his pick, and the latter was with this machine the only part that could suffer in any case. From these remarks it will be gathered that his experience led to a preference for the percussion type of machine in all cases where there was an intrusion of hard material in the coal-seam, and in all cases where space was limited. As to the best make, he had, since writing on this subject nearly two years ago,* continued to work and test the three machines therein referred to, and which were the best known in the market, the Harrison, Ingersoll, and Yoch, and the latter had given the best results: it was a more powerful machine, made a larger undercut (6 feet), covered more ground in a given time, and cost less to keep in repair.

The Dominion No. 1 mine, which he had laid out entirely for machine work, now had a capacity of 2,000 tons a day in its second season, and next year would be equal to a production of 3,000 tons per day. Each Yoch machine produced 50 to 60 tons daily, the cutting rate being 4d. per ton or 1d. per square foot of undercut. At this rate, the operator, after paying his helper 5s. a day and allowing for oil and sundries, earned on an average about 12s. for 8 hours of work. This coal was cut at a much lower cost than that in Iowa; in fact, he questioned whether cheaper coal was produced in any of the United States, and, at the same time, the workmen were earning more money. He noted that Mr. Bain had arrived at the same conclusion as himself, with reference to the enormous benefit of machines for driving headings or narrow work. In the

* *Trans. Fed. Inst.*, vol. xi., page 179.

Dominion mines, he had found a saving of at least 50 per cent., and now heading-coal only cost 8d. a ton more for mining, blasting, and loading than ordinary room-coal, viz. : 1s. 6d. against 1s. 3d. per ton.

Mr. HENRY DAVIS (Derby) wrote that Mr. Bain's paper, conveying the experience gained with coal-cutting machines under various conditions, would, as the subject is now occupying so much attention, be of great value to the members. The pick type of machine was but little known in this country, and where employed had not found much favour, the recoil and excessive vibration being found detrimental and very trying to the operator. It would be interesting to hear from Mr. Bain what effect this recoil had on the health of the operators in Iowa, and whether one man operated the machine for a whole shift—as a reciprocating action, however well constructed the machine might be, must adversely affect the nervous system.

The Jeffrey cutter-bar and the more recent chain-breast machines were doing good service in this country, chiefly in heading and pillar-and-stall work, and in some cases on longwall faces. The chain-machine was undoubtedly a great advance over its predecessor (the bar-cutter); as there were fewer parts, and consequently the machine was lighter, easier to move from stall to stall, and less costly in upkeep. Mr. R. M. Haseltine, chief inspector of mines of Ohio, in his paper on "The Use of Electricity in Coal-mining"* went very exhaustively into the comparative horse-power required to cut coal with various machines, and in comparing the Jeffrey bar with the Jeffrey chain-machine he gave the following results:—

Type of Machine	Jeffrey Chain. 1				Jeffrey Bar. 3			
	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.	Ft.	Ins.
Depth of cut	5	7	5	9	5	7	5	6
Width of cut	2	8	2	7	3	1	2	8·4
	Sq. Ft.		Sq. Ft.		Sq. Ft.		Sq. Ft.	
Area of undercut	15·1		15		17·1		14·8	
	Horse-power.		Horse-power.		Horse-power.		Horse-power.	
Average electrical power used in cutting	8·6		14·5		17		22·7	
	Min. Sec.		Min. Sec.		Min. Sec.		Min. Sec.	
Time occupied in making cut	2	57	3	37	3	54	4	31

NOTES.—No. 1 was a pure coal and cut easily. No. 2 coal was very hard, ten sets of bits being used per shift. This coal was so hard that it had been found impossible to mine it by hand. No. 3 coal was soft. No. 4 coal was very hard, twelve sets of bits were used per shift.

It will therefore be seen that under precisely similar conditions—that is comparing Nos. 1 and 2, and 3 and 4 in similar coal, and nearly the same depth and width of holing with the same kerf, the bar-

* *Colliery Guardian*, 1895, vol. lxx., page 1083.

machine absorbed on an average 50 per cent. more power than the chain-breast machine. Two men were sufficient to operate these machines, and it was considered preferable to select intelligent miners rather than mechanics to work them. Little difficulty was found in accustoming these men to handle the Jeffrey machine, and in many cases it had been put to work successfully without any technical assistance. Apart from reducing the cost of holing, the gain in round coal in itself showed a profit, and Mr. R. S. Williamson stated* that there was an increase of from 12 to 15 per cent. of round coal over that produced by hand labour; and this percentage of round coal was more pronounced in thin seams. At the Gelli colliery, the Jeffrey was holing in a coal-seam, 2 feet 9 inches thick, with an air power-machine of the standard build, viz., 26 inches high, and this height could be reduced to 20½ inches overall in machines (both air power and electric), specially constructed for use in thin coal-seams.

The following paper by Mr. H. V. Winchell, on "The Lake Superior Iron-ore Region," was read :—

* *Trans. Fed. Inst.*, vol. vii., page 307.

THE LAKE SUPERIOR IRON-ORE REGION, U.S.A.

BY HORACE V. WINCHELL.

HISTORICAL.

It is intended in the following pages to give a description of the most extensive and productive iron-mines of the globe—mines whose sudden development and unparalleled richness have had a far-reaching influence on the industrial growth and activity of the entire western hemisphere. Before proceeding to a description of these ore-deposits and an account of the present methods of exploiting them it may be well to recount briefly the salient facts as to their discovery and early history.

A stranger visiting these mining regions for the first time and observing the extensive areas of caved ground, where the underground mines are located, or the large open cuts in which huge steam-excavators are at work taking the ore from its natural bed and loading it into railroad-cars, would not only be surprised at the sight, but were he also to visit the Lake Superior or Lake Erie ports and inspect the vessels engaged in transporting the ore and the facility with which it is handled would scarcely credit the statement that the first ton of Lake Superior ore was mined less than half a century ago, and that the largest production for the year 1895 came from a district that had not yielded a ton of ore prior to the autumn of 1892. No prehistoric workings are here discovered. No trace of implements, crude and inefficient, bear mute testimony of the activity of former races. In a country where all developments are recent the iron-ore industry is especially so, and although of such vast importance is but poorly appreciated by even the well-informed citizen of the very communities in which the mines and furnaces are situated.

In recounting the discovery of the iron ores of Lake Superior extracts will be made from a paper prepared by the author for the Lake Superior Mining Institute. The exact references to this and other works cited in this paper will be found in the list of authorities appended hereto (Appendix A).

Marquette Range.

The actual discovery of iron ore in the Lake Superior region was made by Mr. Wm. A. Burt, United States deputy surveyor, under the direction of Dr. Douglass Houghton, who had taken the contract to finish the linear survey and unite with it geological observations of the country traversed. In 1844, Mr. Burt's party, consisting of Messrs. Wm. Ives, compass-man; Jacob Houghton, barometer-man; H. Mellen, R. S. Mellen, James King, and two Indians, was engaged in establishing township lines and making geological observations in the manner described. On September 19th, while running the east line of township 47 N., range 27 W., using the solar compass invented by Mr. Burt, remarkable variations in the direction of the needle were noticed. In this connexion Mr. Jacob Houghton, one of the party, said :—

At length the compass-man called for "all to come and see a variation that will beat them all." As we looked at the instrument, to our astonishment the north end of the needle was traversing a few degrees to the south of west. Mr. Burt called out, "Boys, look around and see what you can find." We all left the line, some going to the east and some to the west, and all of us returning with specimens of iron ore, mostly gathered from outcrops. This was along the first mile from Teal lake. We carried out all the specimens we could conveniently.

A year later, Mr. Burt made the following statement :—*

The fourteen beds of iron ore above described are the most important ores of iron, for quantity and quality, discovered within the boundaries of this survey . . . It may be reasonably inferred that not more than one-seventh of the number of iron-ore beds were seen during the survey of the township-lines; and if this district of townships be subdivided with care in reference to mines and minerals, six times as many more will probably be found. If this view of the iron region of the northern peninsula of Michigan be correct, it far exceeds any other portion of the United States in the abundance and good qualities of its iron ores.

Mr. Bela Hubbard made a "Report on the Geology and Topography of the District south of Lake Superior, subdivided in 1845 under the direction of Douglass Houghton, deputy surveyor."† He makes the following statements :—

The largest extent of iron ore noticed is in township 47, range 26, near the corner of sections 29, 30, 31, and 32. There are here two large beds or hills of ore, made up almost entirely of granulated, magnetic, or specular iron, with small quantities of spathose and micaceous iron. The more northerly of these hills extends in a direction nearly east and west for at least one-fourth of a mile, and has a breadth of little less than 1,000 feet; the whole of which forms a single mass of ore, with occasional thin strata of imperfect chert and jasper, and dips north 10 degrees east about 30 degrees. At its southerly outcrop, the ore is exposed in a low cliff, above which the hill rises to the height of 20 or 30 feet above the country on the south . . . This bed of iron will compare favourably, both for extent and quality, with any known in our country.

* Mr. Jackson's *Report*, 1849, part iii., page 852. † *Ibid.*, page 833.

As to the discovery of the Jackson deposit, which was the first to be mined in the Lake Superior region, we may quote from the letter of Mr. P. M. Everett to Capt. G. D. Johnson, dated Jackson, Mich., 1845, and contained in Mr. Brook's *Report*:—

I left here on the 23rd of July last and was gone until the 24th of October . . . I had considerable difficulty in getting any one to join me in the enterprise, but I at last succeeded in forming a company of thirteen. I was appointed treasurer and agent to explore and make locations, for which last purpose we had secured seven permits from the Secretary of War. I took four men with me from Jackson and hired a guide at the Sault, where I bought a boat and coasted up the lake to Copper Harbour, which is over 300 miles from Sault Ste Marie . . . We made several locations, one of which we called Iron at the time. It is a mountain of solid iron ore, 150 feet high. The ore looks as bright as a bar of iron just broken. Since coming home we have had some of it smelted, and find that it produces iron and something resembling gold—some say it is gold and copper. Our location is one mile square, and we shall send a company of men up in the spring to begin operations; our company is called the Jackson Mining Company.

The actual discovery of the Jackson location was made by Messrs. S. T. Carr and E. S. Rockwell, members of Everett's party, who were guided to the locality by an Indian chief named Manjekijik. The superstition of the savage not allowing him to approach the spot, Mr. Carr continued the search alone, resulting in the discovery of the outcrop, which he describes, as indicated in Mr. Everett's letter. Previous to the discovery, he was led to suppose, from the Indian's description, that he would find silver, lead, copper or some other metal more precious than iron, as it was represented and found to be "bright and shiny."

On July 23, 1845, articles of association of the Jackson Iron Company were executed at Jackson, Michigan, and by these articles Mr. Abram V. Berry was appointed the first president; Mr. Frederick W. Kirtland, secretary; Mr. Philom Everett, treasurer; and Messrs. George W. Carr and W. A. Ernst, trustees. The location was secured by the permit issued to Mr. James Ganson, and was described by metes and bounds, commencing at a certain large pine-tree, the position of which was fixed by its course and distance from the corner of Teal lake. When the land was surveyed it was bought at \$2.50 per acre.

The Cleveland Mining Company was organized in the following year, the location having been discovered by Mr. Abram V. Berry, and obtained by Dr. Dassels, of Cleveland. In 1846, Mr. Fairchild Farrand explored the Jackson location and mined some ore. The Jackson Company erected a forge in 1847 on the Carp river, three miles east of the mine, under the supervision of Mr. Wm. McNair, and the first iron was made on February 10th, 1848, by Mr. A. N. Barney. In 1850, Mr. A. L.

Crawford, proprietor of ironworks at Newcastle, Pa., took about five tons of Jackson ore to Pennsylvania and worked it up. Two years later a larger amount was taken to Sharon, Pa., by General Curtis, who visited Lake Superior for the purpose of securing better ore for his furnaces. In 1852, about 70 tons were sent to Sharon, and in 1856 was made the first regular shipment, amounting to 5,000 tons.

The deposit of iron ore at Republic appears to have been first discovered by Messrs. J. W. Foster and S. W. Hill in the autumn of 1848. In the report presented to Mr. C. T. Jackson of an exploration of the country lying between Lake Superior and Green Bay is found the following statement by Mr. Foster :—*

After leaving the lake, we saw no exposure of the rocks until we arrived at the north part of township 46, ranges 29 and 30. The river here forms a lake-like expansion, and is bounded on the north-east by a range of hills which rise abruptly to the height of nearly 200 feet above the water.

We explored this ridge on section 1, township 46, range 30, and found that it was composed, for the most part, of nearly pure specular oxide of iron (fer oligiste). It shoots up in a perpendicular cliff 113 feet in height, so pure that it is difficult to determine its mineral associations.

We passed along the base of this cliff for more than $\frac{1}{4}$ mile, seeking for some gap through which we might pass and gain the summit. At length, after much toil, and by clambering from one point to another, we succeeded. Passing along the brow of the cliff, 40 feet, the mass was comparatively pure; then succeeded a bed of quartz composed of rounded grains, with small specks of iron disseminated, and large rounded masses of the same material enclosed, constituting a conglomerate. This bed was 15 feet in thickness, and was succeeded again by specular iron, exposed in places to the width of 100 feet, but the soil and trees prevented our determining its entire width. This one cliff contains iron sufficient to supply the world for ages, yet we neither saw its length nor breadth, but only an outline of the mass. Its bearing could not be accurately determined, but was inferred to be north of west and south of east, with a northerly dip of 85 degrees.

This same deposit is also described in similar terms in Messrs. Foster and Whitney's "Lake Superior."† In his first *Annual Report*, Mr. C. E. Wright states that this property was originally "explored" by Mr. S. C. Smith, and entered by Mr. James St. Clair in 1854, six years after its discovery by Messrs. Foster and Hill. The Republic Iron Company was not organized until October 20th, 1870, and the first ore was shipped in 1872.

The great demand for iron occasioned by the Civil War caused the iron interests, which were well organized at that time, to assume a very successful aspect. Development progressed rapidly, and although expenses were large, the demand for ore was constant and the prices high,

* Page 775. † Part ii., page 22.

so that permanent and prosperous cities like Negaunee and Ishpeming were started and sustained by the iron-ore mining-industry of Marquette county.

Menominee Range.

The earliest reports of iron ore on this range are furnished by those same early geologists and explorers, Messrs. J. W. Foster and S. W. Hill, whose trip across the country from Lake Superior to Green Bay in the autumn of 1848 has already been mentioned. It seems almost incredible that their observations should have lain for so long a period unverified and forgotten, while the search for iron was prosecuted in other parts of the same region. But it was actually more than 20 years before these deposits were rediscovered and thoroughly explored, and even then no credit was given to the true discoverers. Mr. Foster's first account reads as follows :—*

About 2 miles south-east of the lower falls (of the "Twin falls" on the Menominee), near section 30, township 40, range 30, there is a large bed of specular iron ore associated with the talcose and argillaceous slates. It makes its appearance on the north side of a lake, and can be traced $1\frac{1}{4}$ miles in length, and in places is exposed 100 feet in width. It bears nearly east and west, and in external characters resembles that of the iron mountain before described. This bed was first discovered by Mr. John Jacobs, from whom I derived the information, and may be regarded as the southern limit of the iron. The distance from this point to the most southerly point where iron was discovered (on the Marquette range) is more than 50 miles in a direct line. Below the falls there are heavy accumulations of drift, so that the subjacent rocks are rarely seen ; and this bed of iron, if it cross the river, is effectually concealed.

The limestone was also observed, and a bed of marble indicated on the map which accompanied the report. The iron ore was compared with that of Elba, New York and Missouri, and was said to excel them all in value and favourable location. It was pointed out that the natural outlet would be by way of Bay de Noquet on Lake Michigan, the place where Escanaba is now situated, and that it was entirely practicable to construct a railroad to that point. In the *Report of the Commissioners of the Geological Survey of Wisconsin for 1858* are the following remarks by Col. Chas. Whittlesey :—

In 1850, I passed up the Menominee as far as Irwin falls, and examined the rocks to the east of the river in Michigan. Here the magnetic and specular ores were found, and beautifully veined marbles. The system of magnesian slates extending from Carp river, on Lake Superior, westward and south-westward, which embraces the metamorphic limestones and the iron, was then traced to the state line of Wisconsin.

* Mr. Jackson, *loc. cit.* page 777.

During the explorations of the present year, in tracing that system within this state across the Menominee river, I had the satisfaction to find that it produces here both iron and marble, in quantities that are inexhaustible.

I cannot in this note, nor till the analyses are completed, give an idea of the value of the ores, but I am satisfied that whenever a cheap mode of transportation is provided they will attract notice. Both the iron ores and the marbles exist on both sides of the river convenient to water power that is unlimited. A considerable part of the deposits of iron have hard wood near at hand suitable for coal.

Further mention of the "iron range" south-west of Lake Antoine and near Lake Fumée may be found in Messrs. Foster and Whitney's *Lake Superior*.^{*} There is a section† taken from the manuscript of Col. Whittlesey, showing specular iron interstratified with saccharoidal limestone near a branch of Cedar river and near Little Bekuenesec falls on the Menominee river. It is also stated, in this connexion, that Mr. W. A. Burt crossed a low ridge of iron ore in 1846, not far from the corner of townships 41 and 42, between ranges 29 and 30. This was not subsequently met with in running the township lines, but is shown on the geological map of 1873.

In 1867, the region was visited and examined geologically by Dr. Hermann Credner, of Leipzig. His description, in German, was published in 1869, and contained frequent references to the iron ores.

The first systematic exploration was begun in 1872 under the immediate supervision of Dr. Nelson P. Hulst, at that time the agent of the Milwaukee Iron Company, the chief promoters of which were Mr. J. J. Hagerman and Mr. J. H. Vandyke, of Milwaukee, Wisconsin. That the company had made a good choice in their selection of an explorer was soon proved by the discovery of the Vulcan and West Vulcan mines. In 1873, Mr. John L. Buell explored the Quinnesec property and carted the first ore (53 tons) to Menominee, where it was smelted by the Menominee Furnace Company.

The panic of 1873 put a damper on operations for a time. But in 1877 the Menominee Mining Company, of which Dr. Hulst was a member, purchased the leases of the Milwaukee Iron Company, and again started Dr. Hulst on the search for ore. He was again successful, this time discovering the celebrated Chapin mine. This was in 1878, and in 1880 the first shipments were made, amounting to 34,556 tons. The discovery of the Norway mine soon followed (in August, 1878), and thereafter the new range was fully entered in the list of ore-producers from Lake Superior.

^{*} Vol. ii., pages 30; 31, 1851.

[†] *Ibid.*, page 28.

Penokee-Gogebic Range.

The magnetic iron-ore belt of northern Wisconsin was first noted in 1848 by Dr. Randall, assistant geologist to Dr. David Dale Owen, while following the fourth principal meridian northward.

In Mr. Owen's *Report of a Geological Survey of Wisconsin, Iowa, and Minnesota* there is a "Geological Report on that portion of Wisconsin bordering on the South Shore of Lake Superior, surveyed in the year 1849," by Mr. Charles Whittlesey. In this report, which was published in 1852, is a description of the "Magnetic Iron-beds of the Penokie range."* Analyses of iron-ore found there are quoted, which show from 56.3 per cent. to 66 per cent. of metallic iron, and the following statements are made :—

The bed of magnetic iron ore south of Lac des Anglais is of extraordinary thickness—25 to 60 feet. . . . In the wild and deep ravines where the Bad river breaks through the range, there is a cliff of slaty ore, most of which comes out in thin, oblique prisms, with well-defined angles and straight edges, probably 300 feet thick, including what is covered by the talus or fallen portions. I estimate more than one-half of this face to be ore ; and in places the beds are from 10 to 12 feet in thickness, with very little intermixture of quartz. There are portions of it not slaty, but thick-bedded.

The geological occurrence is fully figured and described, and the similarity of this ore to "the extensive mines, or rather mountains, of iron ore in Michigan, described by Messrs. Houghton, Burt, Jackson, Foster, and Whitney," is also mentioned. The idea of exploitation on a large scale is conveyed by the last paragraph :—

The position of the best exposures of ore which I saw is such as to require from 18 to 28 miles of transportation to reach the lake. The nearest natural harbour is in Chegwomigon bay, about 25 miles from the central part of the Penokie range.

The interesting origin of the name "Penokie" was given as follows by Col. Whittlesey in an article on "The Penokee Mineral Range" read before the Boston Society of Natural History in July, 1863 :—

In the Chippeway language the name for iron is *pewabik* ; and I thought it proper to designate the mountains, where this metal exists in quantities that surprise all observers, as the "Pewabik range." The compositor, however, transformed it to *Penokie*, a word which belongs to no language, but which is now too well fastened upon the range by usage to be changed.

Soon after the publication of Dr. Owen's report, the excitement of 1845-46 in reference to copper was repeated in reference to iron. Pre-emptors followed the surveyors, erecting their rude cabins on each quarter-section between the meridian and Lac des Anglais, a distance of 18 or 20 miles. The iron belt is

* Pages 444 to 447.

generally less than a $\frac{1}{4}$ mile in width, regularly stratified, dipping to the north-west conformable to the formations, and having its outcrop along the summit of the second or southerly range.

This paper was accompanied by a geological map of the range prepared by Mr. Whittlesey in 1860, on which the crest of the range and the outcrops of iron ore are marked with wonderful accuracy.

But Mr. Whittlesey was not the only geologist who observed and described the mineral wealth of this region. In 1858, Mr. Edward Daniels, one of the State Geological Commission, and prior to that time state geologist, visited the Penokee-Gogebic range, and mentions it as follows in the Commissioners' Report for 1858, pages 10, 11 :—

The mineral resources also promises richly. The most important of these are the great deposits of iron ore found in the Penokie Mountains, about 30 miles inland from the head of Chegwomigon bay. These iron beds follow the mountain-ridge through several townships, having a direction a little north of east. . . . The ore is principally the magnetic and brown oxide, with traces of specular iron, and occurs in seams parallel with the stratification, varying from a mere line to 50 feet in thickness ; it is of good quality, well-located for quarrying, and practically inexhaustible.

Another well-known scientist who saw and appreciated the ore deposits of this range was Dr. I. A. Lapham, afterward state geologist of Wisconsin. He visited the Penokee district with Mr. Daniels in 1858. His account of the trip may be seen in the *Transactions of the Wisconsin State Agricultural Society*.^{*} He there gives what is perhaps the first published map of the range, and speaks highly of the iron ore he saw there. In a report made by Dr. Lapham to the Wisconsin and Lake Superior Mining and Smelting Company, dated November, 1858, and published in pamphlet form in 1860, we find the following :—

It will be seen that we have already discovered good ore in such quantities as to be practically inexhaustible, situated at points accessible to water-power and having bold fronts, rendering it comparatively easy to be quarried. For many years to come only the richest and most accessible ores can be brought into use, rejecting—at least for the present—all such as have too large a proportion of silica, and such as are not in a condition to be easily and cheaply removed from the natural bed.

Further full accounts of the Penokee-Gogebic range are to be found in the Wisconsin *Geological Reports* for 1878-79.[†]

A brief description of this range, by Messrs. R. Pumpelly and T. B. Brooks, published in the *Report* of the Michigan Geological Survey for 1872, seems to have attracted considerable attention. This report was accompanied by a map on which the belt of iron-bearing rocks is delineated in a general way.

^{*} Vol. v., 1858-59. [†] Vol. iii., pages 100-166.

In 1879, Mr. F. H. Brotherton directed explorations which very closely located the ore-formation for the Canal Company. Subsequent work of development has borne testimony to the accuracy of his field locations, all the mines since found in the district examined by him being on or very near the line which he at that time determined.

The first discovery of soft ore *in situ* and in large quantity is said to have been made by Capt. Nat. D. Moore during the season of 1880. This was on section 15, township 47-46, Michigan. Capt. C. P. Pease commenced explorations on the adjoining section (16) in June, 1881, for the Cambria Iron and Steel Company, and partially developed the Colby mine. Actual mining was begun here in October, 1884, by Captain Moore, and the first ore was shipped on six flat cars over the Milwaukee, Lake Shore, and Western Railway to Milwaukee, and thence to Erie, Pa. This mine surpassed all predecessors in the amount of ore shipped during the first three years after it was opened, but its record has been excelled many times since then.

The Sunday Lake mines were found by Mr. Geo. A. Fay, who conducted explorations in 1881 and 1882 for Mr. D. H. Merritt and others of Marquette, Mich.

During the fall of 1882, test-pitting was started by Capt. Jas. A. Wood for Mr. A. L. Norrie, on the S. $\frac{1}{2}$, S.E. $\frac{1}{4}$, section 22, township 47, range 47. Ore was found almost immediately, and the Great Norrie mine is the result of subsequent explorations and developments on the same ore-body.

The wave of mining stock speculation, which fairly inundated the northern states during the two years following the discovery of these iron-mines, is of too recent date to require description. Suffice it to say that the production of the new range was simply phenomenal, doubling and trebling with unparalleled rapidity, and constituting one of the most remarkable chapters in the mining history of this remarkable district.

Vermilion Range.

The first account of iron ore on the Vermilion range appears in the *Report of the State Geologist* (Mr. H. H. Eames) published in 1866. He says:—*

The iron range of Lake Vermilion is on the east end, on the stream known as Two River, which is about 60 feet wide. . . . This range is about 1 mile in length; it then ceases, and after passing through a swamp, another uplift is reached, from 250 to 300 feet high. The iron is exposed at two or three points between 50 and 60 feet in thickness; at these points it presents quite a mural face,

* Page 11.

but below it is covered with detritus of the over-capping rock. On this account its exact thickness could not be correctly ascertained. The ore is of the variety known as hematite and white steely iron, and is associated with quartzose jasperoids and serpentine rocks. A little to the north of this is an exposure of magnetic iron of very good quality, forming a hill parallel with the one described.

The hematitic iron has a reddish appearance from exposure to atmospheric influence; its fracture is massive and granular, colour a dark steel grey. The magnetic iron ore is strongly attracted by the magnet and has polarity, is granularly massive, colour iron black.

At the request of the legislature of Minnesota, Col. Chas. Whittlesey made a *Report of Explorations in the Mineral Regions of Minnesota during the years 1848, 1859, and 1864*, published in Cleveland in 1866. In this report is a map of Vermilion Lake and the Mesabi iron range. It also contains* an announcement of the discovery of iron ore at the former locality by Mr. Eames. Here Col. Whittlesey gives it as his opinion that workable iron ore exists near enough to Lake Superior to render it of practical value.

The first "shot" was put in the ore at Vermilion Lake by Messrs. George R. Stuntz and John Mallmann in 1875, on the "south ridge." In 1884, the Duluth and Iron Range Railroad was constructed from Lake Superior to the mines at Tower, and mining was begun under the direction of Capt. Elisha Morcom. Afterwards, with a change of ownership, in 1886, the management passed to Mr. D. H. Bacon, president and general manager of the Minnesota Iron Company, under whose supervision subsequent discoveries were made and the mines developed and equipped with one of the finest plants in the country.

The mines at Ely were first opened by Mr. James Sheridan and his associates in 1886; but were soon turned over to the Chandler Mining Company, and are now, with the exception of the Pioneer and Zenith mines, under the control of the Minnesota Iron Company. The record of the Chandler mine, at Ely, has been a most creditable one.

Further detailed accounts of the Vermilion range may be found in *The Iron Ores of Minnesota*, Bulletin No. 6 of the Geological Survey of Minnesota. This bulletin was written in 1890, and published early in 1891, before the opening up of the Mesabi range.

Mesabi Range.†

In 1850, Mr. J. G. Norwood mentioned iron ore as occurring at Gunflint Lake,‡ and stated that it appeared to be in the eastward

* Page 10.

† This spelling of the name "Mesabi" is adopted because it conforms with the usage of the state and national geological surveys for many years, and is in accord with the decision of the National Board of Geographic Names.

‡ Mr. D. D. Owen's *Report of a Geological Survey of Wisconsin, Iowa, and Minnesota*, page 417.

continuation of the hills known farther west as the Mesabi, and which extended to Pokegama falls on the Mississippi river. He did not notice ore in sufficient quantities to impress him with its value as a merchantable ore-deposit, but simply noted its occurrence near the west end of the lake.

Mr. H. H. Eames, the geologist mentioned above, was the first to observe iron ore on the Mesabi range and consider it of any value. In his report of 1866, published in the following year, is an account of the ore on the western end of the range, at Prairie river, together with several analyses, showing it to be of good quality. Mr. Eames took steps to secure title to this property and develop it; but the time had not yet come for the successful prosecution of such an enterprise.

Favourable mention is made of the Mesabi in several other geological reports between that time and 1891. Messrs. N. H. Winchell and A. H. Chester described it at some length in the seventh, ninth, tenth and eleventh reports, and the state was urged to take steps to have it developed. In the volume on *The Iron Ores of Minnesota*, however, may be found the most elaborate discussion of the rocks of this range. The views held at this time, before the actual discovery of any of the numerous deposits since opened up, are well expressed in the following quotations :—*

They (the ores of the Mesabi) are destined to play a very important part in the future development of the iron industry of the state. They occupy fourfold the area that is occupied by the Keewatin ores (Vermilion range), and they are nearer the ore-shipping points as well as the iron-using markets. It is on account of this high promise of future productiveness that they are fully described in this bulletin. . . .

There can be no reasonable doubt that in Minnesota, about the western and north-western confines of the Lake Superior basin and extending westward to the Mississippi river, there will yet be mined greater quantities of hematite than have been taken from that marvel of mining districts, the Penokee-Gogebic range, which blazed out with such a brilliant record only a few years ago.

The first persistent exploration of the Mesabi range for iron ore was made by Messrs. Merritt Brothers, of Duluth, Minnesota, and to them in largest measure must be credited its unprecedentedly rapid development, and to a certain extent, the disastrous consequences to the iron ore interests of the entire Lake Superior region during 1893. The Mountain iron-mine was found on November 16th, 1890, by a gang of workmen under Capt. J. A. Nichols. In August, 1891, the next large deposit was discovered by Mr. John McCaskill, Capt. Nichols, and Mr. Wilbur Merritt. This has since developed into the Biwabik group of

* *Op. cit.*, pages 112 and 160.

mines. In 1892, two railroads were built to the range, and in 1893 the shipments amounted to 620,000 gross tons (2,240 lbs.), while the output for 1894 and 1895 were 1,793,052 and 2,781,587 gross tons respectively. In the years 1895 and 1896, the shipments exceeded those of any other range in the Lake Superior district.

Canadian Iron Ore.

Deposits of iron ore are known to exist in Ontario, north of Lake Superior. Messrs. McKellar, of Fort William, Ontario, have done more than any others to discover the iron ores of that vicinity. Although not yet thoroughly explored by shafting or drilling, it is probable that there is a considerable amount of merchantable ore in the Thunder Bay district which will be of value when the country is more thickly populated. It is not likely that it will ever enter into serious competition with the ore of those portions of the Lake Superior region situated in the United States, owing to its poorer quality and greater cost of production. So far as these deposits are at present developed they do not compare favourably, either in quality or accessibility with those now being exploited south of the international boundary line.

In a recent letter, Mr. A. Blue, minister of mines of Ontario, speaks as follows regarding iron ores in Ontario :—

There is only one property (on the Atik-okan) upon which deep prospecting has been done, and this was with a drill on a location which shows for the most part a lean ore at the surface. The most promising locations have not been prospected at all, beyond the sinking of a few pits upon them. On this point I can speak with some confidence, for I went over the range this summer. The deposits of magnetic ore are very large on the Atik-okan river, but as they are at least 50 miles from a railway, there is little hope of their being worked immediately. . . .

But there is another iron range in the Lake Superior region of Ontario. . . . It is about 50 miles farther west than the Atik-okan, and is supposed to be a continuation of the Vermilion range of Minnesota. I went over a portion of it last summer. It is hematite ore of 50 to 55 per cent. richness.

Thus, from the testimony of the Canadian authorities, the Ontario iron-ores cannot compete with those of Michigan and Minnesota. For ores which carry but 55 per cent. of iron certainly cannot be shipped from the northern shore of Lake Superior at a profit at prevailing prices.

It is thus evident that only 40 years have elapsed since the first regular mining of iron ore was inaugurated in the Lake Superior region. The date of first shipments and total output to January 1st, 1897, in gross tons are as follows for the five ranges :—

		First Year.			Gross Tons.
Marquette range	...	1856	...	...	46,538,187
Menominee "	...	1880	...	...	22,994,428
Penokee-Gogebic range	...	1884	...	...	20,788,787
Vermilion	"	1884	...	...	9,220,235
Mesabi	"	1892	...	...	8,074,583
Miscellaneous	...		...	...	2,320
Total production to date					107,618,540

The shipments from this district for 1896 were 9,934,828 tons, while the average output for 40 years has been 2,690,467 gross tons per annum. (Appendix D.)

GEOGRAPHICAL.

These iron-ore belts or ranges lie chiefly in the two states of Michigan and Minnesota. The upper peninsula of Michigan is on the south side of Lake Superior. In it are located the Marquette, Menominee, and Penokee-Gogebic iron ranges, as shown on the sketch map accompanying this paper (Fig 1, Plate XXIII.). The Menominee and Penokee-Gogebic ranges extend westward into Wisconsin, but they have thus far not proved very productive in the latter state.

The Vermilion and Mesabi ranges, so far as developed and productive, are situated entirely in St. Louis county, Minnesota. It should not be inferred from this statement, however, that the iron-producing territory is confined to a limited area, for this county, with its area of 5,860 square miles, is as large as some empires or as some states of the United States.

Lake Superior occupies a basin or depression in the earth's crust. The longer axis of this basin is nearly east and west, and has a length of about 400 miles. This basin is about 2,500 feet deep, and at its deepest part or lowest point is 400 feet below the level of the sea. It is filled with fresh water up to the level of 602 feet above tide-mark, and the hills which form its coasts are from 1,000 to 1,600 feet still higher. Near the crests of these glaciated east-and-west hill-ranges are found the belts of rock which contain the iron-ore deposits. The mines are thus situated several hundred feet above the water on whose surface the ore is transported to the eastern furnaces.

The distance from the mines to the lake varies from 30 to 100 miles on the different ranges, and by different lines of railroad. The distance from the loading docks or shipping ports of the mines to the unloading docks or receiving ports on Lake Erie also varies from 523 to 823 miles, and as a consequence some mines can market their product more cheaply than others. This will be more fully explained under the head of transportation.

The different ranges have a length of possibly productive territory about as follows :—

Marquette, from township 48, range 26, to township 48, range 31, a length of 35 miles.

Menominee, from township 39, range 28, to township 45, range 32, a length of 45 miles.

Penokee-Gogebic, from township 44, range 6, to township 47, range 42, a distance of more than 80 miles.

Vermilion, from township 63, range 11, to township 60, range 26, a distance of about 100 miles.

Mesabi, from township 65, range 4, to township 56, range 24, a length of more than 150 miles, of which the western half is by far the most extensively developed and most promising for the future. The actually productive extent of these ranges is much less than the figures given above, and in the case of the Vermilion range the developments are confined to two localities 21 miles apart.

GEOLOGICAL.

Owing to the great extent of territory and its inaccessibility until very recently, as well as to the newness of the country generally, careful geological observations have been made in only a portion of the Lake Superior region. Thus the Canadian Geological Survey has studied certain rather limited areas, and on the facts observed there, the surveyors have to a greater or less degree been tempted to generalize over the whole of the territory lying north of Lakes Huron and Superior. The same may be said to apply more or less perfectly to the work of the United States Geological Survey and the labours of the different state surveys which are at work in this region. Considerable confusion as to classification and many differences of opinion exist between these various geologists on some of the more important and many of the minor questions as to stratigraphy and geologic relationship in this region. Hence it is impossible to state positively the age and equivalents of the iron-bearing rocks. In order to avoid ambiguity and to permit the reader to ascertain at a glance the significance of the geological names that may be employed in this paper the accompanying table (Appendix C) of the comparative nomenclature and classifications of different geologists is quoted from the *Twenty-first Annual Report** of the Minnesota Geological Survey. For further information the reader is referred to Prof. Van Hise's correlation papers on the Archaean and Algonkian formations.

* Opposite page 4.

In General.

The iron ore deposits in question occur in rocks which are of pre-Silurian and probably of pre-Cambrian age. These rocks are chloritic and hydromicaceous schists, intrusive dykes and bosses of diabase and diorite, ancient volcanic tuffs, fragmental conglomerates, quartzites, quartzose and argillaceous slates, limestones and sideritic rocks, and non-fragmental ferruginous cherts and jaspers. The ore-deposits and the enclosing rocks dip under the lake on both sides, at various angles from nearly horizontal to nearly vertical.

The determination of the geological age of these strata rests wholly on structural evidence. No undoubted organic remains have yet been found in the ore or the enclosing rocks. Mr. W. S. Gresley has recently announced the discovery of supposed annelid trails in the iron ore from the Chapin mine, as found on the ore-docks at Cleveland, Ohio. This discovery, if it proves to be such, will have an important bearing on the questions of age and origin of these ores. Mr. J. E. Spurr has advanced the theory of an organic origin of the Mesabi and possibly Penokee-Gozebic ores through the agency of foraminifera and other organisms which are supposed to have formed deposits of glauconite which has subsequently been transformed into iron oxides. This theory will be reverted to again. The geological features of these different ranges may now be taken up in more detail.

Marquette Range.

The rocks of the Marquette have been the subject of much discussion by geologists. This range having been the first to produce ore, and having been by far the largest producer of the district, its literature is older and more voluminous than that of any other. The eminent names of Messrs. Brooks, Irving, Pumpelly, Rominger, Van Hise, Wadsworth, N. H. Winchell, and Wright, are all indissolubly connected with its study and geological elaboration.

The geological structure of this range, as of the Menominee in Michigan and the Vermilion in Minnesota, is complex, and difficult of elucidation. In fact, the presence of two unconformable iron-bearing series was overlooked entirely by the early investigators. The formations of this range are as follows, beginning at the lowest :—

(1) Gneisses and crystalline, micaceous and hornblendic schists, differently called Laurentian (including the Couthiching), Cascade and Basement Complex.

(2) Keewatin schists, greenstones, slates, conglomerates, iron ores, and jaspers. This horizon is called also Lower Huronian or Huronian, and Lower Marquette, and is divided by Mr. Wadsworth into the Republic and Mesnard, of which the former is the older, and is supposed to be unconformably overlain by the latter.

(3) Upper Huronian quartzite, slates, and iron ores, corresponding in a general way with the Animikie, Upper Marquette, Upper Menominee, Penokee-Gogebic, and Michigan formations as differently named in various sections of the Lake Superior district.

Between (1) and (2) there is believed to be an eruptive unconformity, and perhaps a long erosion-interval. Between (2) and (3) there exists one of the greatest unconformities and erosion-intervals of geological history. The youngest formation mentioned above may be of Lower Palæozoic age. The others are probably Archæan.

As might be expected, these strata present themselves in steeply inclined positions and under highly metamorphosed aspects. Metamorphism has been caused both by the action of the heat and pressure which accompanied the intrusion of ancient eruptive rocks and the earth-movements which attended the folding of the rocks to the positions which they now occupy.

The lower iron-formation of the Marquette range (No. 2 above), usually denominated Lower Huronian or Keewatin, is composed of the following :—

(a) Basal conglomerate and quartzite resting unconformably upon the gneisses and holocrystalline schists. Thickness, from 50 to 100 feet.

(b) The lower iron-bearing series proper, consisting of two members, the lower one composed of actinolite or grünerite, magnetite and silica; the upper usually characterized by bands of red jasper and specular hematite.* The maximum thickness exceeds 1,000 feet.

The Upper Marquette iron-ore horizon, also called Animikie or Upper Huronian, is composed of :—

(a) Basal conglomerate and quartzite.

(b) Calcareous argillites, sandstones, and slates, often becoming semi-crystalline and schistose.

(c) Various intrusive dykes and sheets of diabase, diorite, etc.

The conglomerate contains many water-worn pebbles of granite and fragments of the jasper and ore-formation on which it rests in places. At such points it is quite similar in appearance to the underlying ore-forma-

* Mr. H. L. Smyth, *American Journal of Science*, vol. xlvii., page 218.

tion, and its true unconformable relationship to the latter was not discovered until recently. So numerous are these fragments of ore and jasper that they sometimes constitute merchantable ore-deposits. Where this conglomerate rests immediately upon the gneisses and schists of the Laurentian it resembles the basal conglomerate of the Keewatin or Lower Huronian, and contains but few jasper pebbles.

Structural Relations of Ore Deposits.

The different iron-ore deposits of the Lake Superior region have many points of similarity with each other, especially in their relations to the enclosing rocks. They are of irregular, roughly lenticular form, and usually correspond quite closely in strike and dip with the strata in which they lie. Both ore-deposits and country-rocks are found tilted up to angles which generally exceed 60 degrees, and on the Marquette and Vermilion ranges the dip is almost vertical or at a high angle to the north.

The pure ore lenses are almost invariably associated with jasper composed of alternate bands, or of an intimate mixture of silica and oxide of iron. The silica-bands vary in colour from white to black through various shades of red, yellow, and purple, depending on the amount of intermingled iron oxides. These bands are frequently folded and twisted into most intricate and beautiful patterns, and make a fine showing on smooth glaciated surfaces. The silica of this jasper is not believed to be of fragmental origin. It occurs in minute grains or crystalline individuals, whose origin is still a matter of investigation and will be referred to in another place.

The ore-deposits occupy certain wellknown horizons and relations to the country-rocks. They are found, in the Lower Huronian, at the contact of the basal quartzite and the ferriferous rocks which lie next above it, or else entirely within the latter. In the former case, the ore is frequently hard or specular. In the latter case, it may be hard, but is more often soft. These soft ores are frequently associated with more or less altered, impervious, intrusive dykes or hardened portions of the strata in such a way as to suggest a relation of cause and effect. Similar phenomena are noticed in some of the other Lake Superior ranges, and especially on the Penokee-Gogebic range.

These intrusives are usually very much decayed and softened, where they are encountered in the ore-bodies, and their original nature is changed so that they appear like reddish bands or layers of impervious clay. This clay is frequently called "paint rock" by the miners, and is often found on the lower side or edge of the ore.

Menominee Range.

The iron-bearing formation of the Menominee is supposed to be a portion of the Lower Huronian, and to be generally equivalent to the Lower Marquette. The following succession of strata is given by Mr. Smyth,* who suggests that the Lower Menominee is older than the Lower Marquette, and that the principal ore-horizon of the Menominee may have no equivalent in the neighbouring Marquette district:—

(a) Basal quartzite, rarely conglomeratic, having a maximum thickness of about 1,000 feet.

(b) Crystalline limestone, averaging about 700 to 1,000 feet in thickness.

(c) Red, black, and green slates, not more than 200 to 300 feet in thickness. These rocks contain the chief iron-bearing horizon. They are sometimes accompanied by altered eruptives of considerable thickness.

(d) The Michigamme jasper : a ferruginous rock supposed to have been originally, in part at least, a clastic sediment ; but which is now highly altered so as to resemble the banded jasper of the Marquette range.

Iron ores occur at three horizons, viz., between the quartzite and limestone, in the slates, and in the Michigamme jasper. The chief mining operations are at Iron Mountain and Norway.

No limestone corresponding to this of the Menominee range is found in any of the other iron-ore districts. It is a fine-grained, buff-coloured rock that has been of great practical assistance in guiding explorations for ore.

The Menominee hills rise about 350 feet above the general level of the surrounding country, and the range is about 1,200 feet above Lake Superior. Capping the hills and forming a fringe around their summits are the sandstones of the Lake Superior Potsdam, resting in a nearly horizontal position on the rocks and ore-deposits of the iron-bearing series.

Penokee-Gogebic Range.

The rocks of the Penokee-Gogebic range are, as has been already stated, younger than those of the Lower Marquette and Menominee, and are generally called Upper Huronian or Animikie. This series of strata has approximately an east-and-west strike, and a northerly dip of about 65 degrees. It rests upon the gneisses and schists of the Archæan, and is overlain by various Keweenawan eruptive rocks.

* *American Journal of Science*, 1894, vol. xlvii., page 217.

The lowest member of the series is a cherty limestone member, which is not always present. Its maximum thickness is about 300 feet. The second member, which sometimes constitutes the basal member, is a quartzite or felspathic quartz-slate which has an average thickness of 300 or 400 feet. The third member of the series is a belt of "non-fragmental sediments" about 800 feet thick.* This member consists of ferruginous banded slates and cherts, and constitutes the chief iron-ore horizon. The ore is usually found at its base, resting upon the underlying quartzite. The uppermost member of the series is made up of greywackes, slates and mica schists. Intrusive dykes and sheets of greenstone are found in that portion of the range where mining developments are in progress. These dykes appear to have played an important part in the formation of the ore-deposits, and will be mentioned more particularly in the discussion of the origin of the ore.

Vermilion Range.

This iron-ore belt lies north of Lake Superior, and so far as at present developed is wholly in Minnesota. Its general trend is nearly east and west, and its strata have an almost vertical dip. They are supposed to be equivalent in age to the older rocks of the Marquette range, and are called Keewatin or Lower Huronian. Owing to complexity of folding and the presence of ancient intrusive rocks which, together with the clastics, have been highly metamorphosed, the geological structure and order of superposition have not as yet been clearly unravelled, although the district has been the field of study of the Minnesota geological survey for two or three seasons.

The rocks found on the Vermilion range are conglomerates, quartzites, greywackes, slates, jasper-schists, sericite and chloritic schists, and various forms of altered eruptives. The relations which subsist between the ore and the enclosing rocks are in a general way similar to those described on the Marquette range.

The ore-bodies are irregular-shaped masses of hematite of varying dimensions. They are always associated with banded jasper, and usually occupy a relatively lower position topographically than the jasper which constitutes part of any given jasper-and-ore lenticle. Green schists, which have at times the aspect of eruptives and again the aspect of altered elastics, are also closely associated with the ore.

* Mr. C. R. Van Hise, *American Journal of Science*, vol. xxxvii., page 33.

Mesabi Range.

Lying unconformably above rocks which are believed to be the parallel of those of the Vermilion range, and about 20 miles farther south, is the Mesabi range, also in Minnesota so far as developed at present. These rocks are of the same age as the Upper Marquette, Upper Menominee, Penokee-Gogebic, and the Animikie. They dip to the south at an angle of about 12 degrees, making the ore-deposits more nearly horizontal than vertical, and thereby giving rise to different methods of exploitation and practical problems of much novelty and interest. The formations of the Mesabi are as follows :—*

(a) The underlying Keewatin rocks already described as constituting the Vermilion range. These schists are cut by intrusive granites. They crop out along the northern edge of the Mesabi and in one elevated tongue which extends for 10 miles in a southwesterly direction from the upper edge of the range, uplifting the iron-bearing formation and bearing on its flanks many of the large mines of the district.

(b) A basal conglomerate-and-quartzite member resting unconformably on (a), with a thickness of from 10 to 300 feet.

(c) The iron-bearing member or taconite horizon. This is apparently conformable with the quartzite. It has a maximum thickness of 800 or 1,000 feet, and narrows down to a feather edge at the northern edge or outcrop. It is chiefly composed of non-fragmental silica, carbonates of iron and lime, silicates, hydrates and oxides of iron in the form of glauconite, limonite, hematite, and magnetite. The rock which appears to be the earliest form of this taconite is described by Mr. J. E. Spurr as follows :—

In a ground-mass of cryptocrystalline chalcedonic or finely phenocrystalline silica, are thickly strewn rounded or subangular bodies, made up chiefly of a green mineral very slightly pleochroic and without cleavage; under crossed nicols it appears in some places amorphous, in others extinguishing as an aggregate.

This mineral was determined to be glauconite or greensand, and is believed to represent the original form of the iron ore, or to use a miner's phrase, to be "the mother of the ore."

The taconite takes on at different times and places a variety of textures, from aphanitic to coarse and rough, and exhibits nearly all the colours of the rainbow. It also frequently contains fragmental grains, pointing to a mingled mechanical and chemical origin.

* Messrs. H. V. Winchell and J. E. Spurr, *loc. cit.*

GENESIS OF THE ORES.

Theories of the genesis of Lake Superior iron ores are nearly as numerous as the writers on the subject. In this place no attempt will be made to enter into an exhaustive discussion of the subject. Reference will simply be made to the most important theories, and a few brief considerations given as to the theory adopted by the present writer. The origin of the ores of the different ranges is all discussed under one head, because the similarities and differences can best be pointed out in that way. A more complete discussion of the subject will be found in *Bulletin No. VI.* of the Minnesota Geological Survey,* and in recent writings of Prof. Van Hise.

Theories Proposed.

The principal theories are (1) that the ores are of eruptive origin, (2) that they are mechanical sediments, and (3) that they are of chemical origin. Under the third head, the chemical action may have been that of original precipitation or that of replacement or segregation of chemical or clastic materials by the substitution of iron oxides.

Eruptive Theory.—This theory of the genesis of iron ores is now obsolete, except as applied to certain segregations in basic magmas. It was the Huttonian doctrine carried into the realm of ore deposition, and was undoubtedly the most popular theory of the period from 1800 to 1860, or 1870. Among its supporters are found the names of Mr. W. W. Mather, Sir R. I. Murchison, Messrs. J. W. Foster, J. D. Whitney, Ebenezer Emmons, H. D. Rogers, B. von Cotta, C. E. Wright, A. R. C. Selwyn, J. W. Dawson, and M. E. Wadsworth. The last four geologists are the most recent and the last one the most insistent advocate of this theory. The latest writings of Dr. Wadsworth, however, indicate a "change of heart," and he even states that it is "quite probable that I shall have to abandon entirely the view that any of the ore and jaspilite is eruptive."† And he makes the additional statement:—"That the original jaspilite and ore of the Republic formation are of a detrita origin; that they were originally conglomerates, breccias, sands, and muds; and that they have subsequently been acted upon by percolating waters."

The chemical and mineralogical characteristics and environments of the iron ores, as well as their structural relationship to the enclosing

* "The Iron Ores of Minnesota," by Messrs. N. H. and H. V. Winchell.

† *Michigan Geological Survey*, 1891 and 1892, pages 107, 108.

rocks, are such as to effectually preclude the adoption of the eruptive hypothesis, and it may be passed over without further consideration.

Large deposits of titaniferous magnetites are found at various points in the region under discussion, chiefly in Minnesota. None of these ores are mined, however, and their origin is not considered in this paper. There is little reason to doubt, however, that these ores are in one sense of eruptive origin, and are entirely distinct in chemical composition and in geological habit from the merchantable ores.

Sedimentary Theory.—The formation of iron ores by mechanical transportation and oceanic sedimentation, or by concentration in shore-deposits which were subsequently buried and consolidated and subjected to more or less chemical alteration, has been suggested by several writers, notably Messrs. E. Hitchcock, J. P. Kimball, B. von Cotta, B. J. Harrington, and A. A. Julien.

Mr. A. A. Julien has imagined that the conditions under which the Huronian ores were formed :—

Consisted of a shore of some quartzose rock, rich in magnetite, whose *débris* the waves and currents strewed over the sea-bottom, alternately with thin sheets of quartz-granules and magnetite-crystals, partially concentrating the one or the other material in numerous heaps or thicker layers.

In the progress of the metamorphism and contortion to which the layers were subjected, their compact and lenticular forms were further developed, the magnetite was further oxidized, partially as martite, or completely as specular ore (as already suggested by Messrs. Brooks, Credner and others) and assumed, at points where the contortion and pressure became intense, the micaceous structure and brilliant lustre of iron ore, by a process similar to that which produces "slicken-sides."

Recent investigations have shown that but a very small amount of fragmental material is contained in the Lake Superior jasper-and-ore lenticles. The silica is almost wholly non-fragmental, and the iron oxides have lost all traces of shore-action, if they ever possessed any. Moreover, the real source of the iron is not accounted for on this theory, which attempts merely to explain the formation of the large masses and beds of iron ore as we find them to-day. And it is perhaps as difficult to account for the existence of a "quartzose rock rich in magnetite" earlier than the Keewatin, which could by erosion have furnished the Keewatin strata with their ores. Moreover, black sand-deposits almost invariably contain much ilmenite, and the ores in question are singularly free from titanium. Other obstacles to the sedimentary theory will suggest themselves to the reader, and might be mentioned; but these are perhaps sufficient.

Discarding, then, the sedimentary theories, we have left the various chemical theories.

Chemical Theories.—These may be classified as follows:—*

(a) Changes *in situ*.

1. Change in the kind or quantity of iron already present in the rocks.
 - (a) Alteration of diffused ferric oxide into ferrous carbonate.
 - (b) Metamorphism of bog-ore.
 - (c) Metamorphism of lake-ore.
 - (d) Alteration of ferrous carbonate or sulphide of iron into ferric oxide.
2. Change in the kind or quantity of other minerals.
 - (a) Substitution of iron oxide for some non-feriferous mineral.
 - (b) Concentration, by removal of other constituents. Similar to 1a.
 - (c) Electro-telluric action.

(b) Removal by chemical action and subsequent deposition.

1. By action of heat—sublimation.
2. By action of water.
 - (a) In drainage-basins—
 - (1.) Oceanic precipitation.
 - (2.) (a) Secondary product of the decomposition of basic rocks.
 - (b) Secondary product from the decomposition of pyrite.
 - (b) In the rocks—
 - (1.) Saturation of porous strata.
 - (2.) Infiltration into cavities.
 - (c) Deposit by springs.

Several of these theories have not been applied specifically to Lake Superior iron ores, and some of them are manifestly inapplicable. The first one of any particular importance in this connexion is "alteration of the carbonate or sulphide of iron into ferric oxide." This theory has been propounded and ably supported by Profs. Irving and Van Hise, the latter of whom believes it to be a sufficient explanation for all the iron ores of the Lake Superior region. His views may be briefly quoted as follows:—†

The forms, attitudes, and relations of the ore-deposits render it evident that they are not eruptives. No eruptive would be found in such strange shapes and relations. It is equally certain that these irregular masses of ore are not produced directly by sedimentation. All the facts bear toward the conclusion that the ore is a secondary concentration produced by the action of downward percolating waters.

He then proceeds to show that the ore-deposits of the Marquette and Gogebic ranges sustain certain peculiar relations to dykes and sheets of rotted and more or less impervious eruptive rock:—

* Mr. H. V. Winchell, *Report on the Mesabi Iron Range, 1892*, page 70.

† *American Journal of Science*, vol. xliii., page 125.

That the tilted bodies of diorite or soap rock, especially when in a pitching synclinal or forming a pitching trough by the union of a dyke and a mass of diorite must have guided downward flowing waters is self-evident. . . . If it is true that the whole of the iron-bearing formation was originally a lean cherty carbonate of iron, with perhaps some calcium and magnesium, or if we go no further back than the ferruginous cherts and jaspers, it is then concluded that in order to produce the ore two things must have occurred: first, the concentration of iron oxide in the places where are found the ore-bodies; and second, the removal of silica from these places. . . .

Surface-waters bearing oxygen passing downward through the Upper Marquette series or the iron-bearing formation of the Lower Marquette series would decompose the iron carbonates with which they came in contact and thus become carbonated. These carbonated waters would then be capable of taking other iron carbonate into solution. . . . The oxides or carbonates of iron may also have been taken into solution by organic acids. These downward-moving waters would pass through the iron-bearing formation until they came in contact with an impervious substance. . . . Here would be carried other oxygen-bearing waters more directly from the surface. The union of these two currents would precipitate the iron oxide. The abundant waters traversing these ore-bearing localities would also slowly dissolve the silica."

He says again :—*

The ore-deposits of the Upper Marquette series, so far as studied, show that the original material was an iron carbonate, and that the ores are secondary concentrates resting upon impervious formations.

Sometimes this impervious formation is a black slate; at other times it is an intrusive basic eruptive; and at still others it is a surface volcanic. . . .

The ores of the Vermilion Lake district have been studied by us only in a general way, but so far as our investigation has gone all the facts bear toward the conclusion that the principles which here hold are applicable to the other iron-bearing districts of the Lake Superior region.

The writer takes no exceptions to this theory as applied to the Michigan iron ranges, with which he is not so familiar as the professor quoted. But, as will be seen later, he does not accept the theory of derivation from lean cherty carbonate of iron for the ores of the Vermilion range, because of the absence of unaltered carbonates in sufficient quantity to suggest such an origin; nor for the ores of the Mesabi range because of the presence of another ferriferous compound which is earlier in form and genesis than any of the carbonates present. Moreover, the theory advanced by Prof. Van Hise leaves us still in doubt as to the nature and mode of formation of the cherty carbonate, and if this were supposed to be of chemical origin, and as indicated by its deposition over such great areas, of oceanic chemical origin, we would perhaps find it difficult to explain why and how the carbonate and not the hydrate or oxide of iron was precipitated.

* *Loc. cit.*, pages 129, 130.

The theory of oceanic precipitation advanced in 1889* by Mr. N. H. Winchell and the present writer was essentially novel as applied to iron-ore deposits. But the developments and observations of recent years have only served to strengthen our belief in the general correctness of that idea, while at the same time modifying it in some minor particulars. The peculiarly complex phenomena presented by the jasper-and-ore lenticles of the Vermilion range, and the wide extent and uniform character of the taconite of the Mesabi may all be most satisfactorily accounted for on the general theory of chemical formation in oceanic waters either with or without the aid of organic forms. There is no reason to suppose that all iron-ore deposits had a similar genesis, or indeed that any two have had identically the same history. There has been too great a tendency toward generalization already, and it is the conviction of the writer that the conditions are so different on the Minnesota iron ranges from those which obtain in Michigan, that there may well be a different explanation of the ores of the two regions. However that may be, we wish to advance very briefly the following outline of a theory of the origin of the Minnesota iron ores, taking up first the older range.

Origin of Vermilion Ores.

It soon becomes apparent to a student of those ore-deposits that the jasper-and-ore lenticles are entirely distinct mineralogically, chemically, structurally, and genetically from the enclosing rocks, and yet that there is a constant and intimate connexion between them in point of date and manner of origin.

The enclosing rocks are sediments, but sediments of a very peculiar variety. They are among the oldest, perhaps indeed the very oldest undoubted sediments of the earth's crust. They are basic and agglomeratic, composed in large part of volcanic ejectamenta that fell into the waters of the Keewatin ocean. This ocean was agitated and heated by constant outbreaks of the basic ejections which the interior of the earth alone affords. The decomposition of the basic minerals was a rapid and continuous process, and even the more insoluble elements were taken into solution in the ocean's waters. Precipitation of the least soluble substances, such as silica and iron oxide or hydrate would regularly occur in the vicinity of the volcanic vents which marked the loci of the greatest disturbances and produced the ejectamenta. Thus without the

* Messrs N. H. Winchell and H. V. Winchell, "On a possible Chemical Origin of the Iron Ores of the Keewatin in North-eastern Minnesota," *American Geologist*, November, 1889, page 291.

agency of organic life, and prior to its existence upon the earth, solution and precipitation of silica and ferric hydrate must have taken place in the ocean water.*

This silica and intermingled iron oxide was naturally deposited in the lenticular forms typical of oceanic deposits and soon covered up and involved in the mass of Keewatin sediments.

When at a later period these lenticles of jasper and ore were presented in a tilted position to the action of atmospheric waters, a rearrangement and separation of the iron oxides and the silica took place, and the iron was concentrated in the lower portion of the lenticles, with a capping of jasper frequently remaining covering a large portion of the ore, and perhaps grading down into it. This rearrangement and segregation of the silica and iron oxides is probably the cause of the banding of the jaspers as well as their more complete concentration into the merchantable ore-masses. The recognition of this fact followed close upon the study of the Mesabi ore-deposits in 1892, and constitutes the chief modification of our theory as published in 1889.

Few traces of iron carbonates are found on the Vermilion range, and these appear to be largely of later date than the other constituents of the ore-formation. On the other hand, the earliest material distinguishable by microscopic examination is the jasper, composed of minute crystalline quartz-grains, containing and intermingled with small particles of hematite and magnetite. It is not improbable that there has been some change in the composition of this ore-forming rock. It may possibly not have been originally silica and ferric hydroxide, although that appears to the writer far the most likely supposition. It may have been a carbonate or a silicate; but whatever it was it was in all probability an oceanic precipitate.

Origin of Mesabi Ores.

As already stated, the rocks of the Mesabi range are of much more recent date than those of the Vermilion, and although fossils have not yet been found,† it is quite likely that life existed in abundance in the ocean waters while the Mesabi strata were being formed.

* Compare Sir Henry De la Beche, *Geological Observer*, 1851, pages 131, 526-536; Dr. T. S. Hunt, "The Chemistry of the Primeval Earth," *American Journal of Science*, January, 1858; *Smithsonian Report*, 1869, pages 186, 189; *Chemical and Geological Essays*, 1878, page 40; *Geol. Can.*, 1863, page 574; Mr. A. Winchell, *Sketches of Creation*, 1870, page 59; Bernhard von Cotta, *Treatise on Ore Deposits*, Prof. Prime's translation, 1869, page 22; and Prof. G. Bischof, *Chemical and Physical Geology*, vol. i., pages 143, 146.

† The author has in his possession specimens of manganiferous dendrites so similar in appearance to the so-called organic forms pictured by Mr. Gresley in his paper in the *Transactions of the American Institute of Mining Engineers* that he is constrained to receive with very little credence, the notion that the latter are truly of a fossil nature.

The oceanic origin of the Mesabi taconite is perhaps even more clearly established than that of the Vermilion jaspilite. The great extent of this taconite-formation has already been referred to. It lies just above a quartzite which marks a former shore line of the Taconic ocean.

From the researches of Mr. J. E. Spurr it is shown that the taconite was originally a greensand or glauconite-deposit. The earliest stage of the taconite appears to be a glauconite in which the hydrous silicate is already breaking up into iron oxide and free silica. From this stage the process of ore-formation has been followed step by step and clearly explained.

The conditions necessary for the formation of a large body of pure ore, and the situations in which they occur, are quite simple, and were explained in detail by the writer in 1892.* Briefly summarized, they are as follows:—

These ore-bodies, without any notable exceptions, lie just below the glacial till, which varies in depth from a few inches to 150 feet. The ore-deposits themselves have depths fully as variable and in many instances much greater, attaining a maximum thickness of perhaps 350 feet.

The deposits are often wedge-shaped, with the narrow edge near the margin of the formation and the thicker portion lying at greater depths. There is occasionally a knoll or ridge of unaltered taconite resting on the ore or extending into it from the sides or bottom. Frequently the transition from ore into taconite can be observed. This change is sometimes by imperceptible gradations, the iron increasing and the silica diminishing; and sometimes quite sudden. In the latter case there is usually a joint or fault-line between the ore and the taconite, and examination of the taconite near this fault-line will show that the solutions which dissolved the silica and concentrated the ore entered but a short distance, if at all, into the taconite, but were deflected directly downward by the fissure and hence left the taconite unaltered.

The accumulation of Mesabi ore cannot be in any way due to dykes of eruptive rock, as suggested by Prof. Van Hise, for there are none associated with the ore. Dykes and troughs are unnecessary features, the ore being due to a replacement and concentration-process which has proceeded on all uninterrupted slopes of sufficient pitch where the proper rocks exist for such a change. This operation of replacement, moreover, extended as far down the slope as the local conditions have permitted since the rocks were elevated to their present position and exposed to the

* Minnesota Geological Survey, *Twentieth Annual Report*.

influence of atmospheric agencies. If the slope was a long one and in the shape of a large basin the ore-deposit is large. If it was narrow or interrupted by numerous gorges or ridges, the ore is apt to be limited in quantity and of poorer quality. Where there has been an opportunity for the greatest freedom of drainage and the most extensive percolation of ground waters downward through the rocks for a considerable thickness and over a considerable area, there are found the largest and purest accumulations of ore.

There are some deep, narrow deposits which from their shape suggest alteration, concentration and deposition along a fault-line; but it is certain that many of the ore-beds were formed without any reference to or connexion with faults. The dip of the ore is in a general way conformable with that of the rock strata and is, as already stated, about 12 degrees.

From the explanation which has been given of the origin of Mesabi ore by removal of the silica and concentration of the iron through downward percolating atmospheric waters it becomes evident that the width of the ore-belt is limited to the width of the outcropping taconite. This outcrop is bounded on the north by the underlying quartzite and on the south by the overlying black slates, and its width varies considerably, depending on the actual thickness of the taconite, its dip and the local topography or slope of the ground below the glacial till. The conformation of the surface of the ground frequently obscures the real conditions as to slope and drainage of the upper surface of the taconite. Thus we may and do find iron-mines on top of hills or in other apparently anomalous situations when considered from the standpoint of superficial topography alone; but subsequent work of development has never yet failed to show that the ore is after all so situated as to come under the conditions mentioned, and that it lies on some slope or hillside below the superincumbent till, where atmospheric waters have effected the change from taconite to ore. The actual width of the possible ore-producing belt on the Mesabi range is seldom more than 2 miles and frequently less than 1 mile. The ore-deposits themselves may lie at either side or in the middle of this belt, and may have their longer axis across or parallel with the outcrop, though it is generally more nearly the latter.

The different situations in which the ore may occur with relation to the taconite is shown in Figs. 2 to 7 (Plate XXIII.), which are after those published by the writer in 1892. For more detailed accounts of the nature and occurrence of Mesabi ores the reader is referred to the papers mentioned in the list of references by Mr. J. E. Spurr and the author.

MINING.

The different conditions obtaining at Lake Superior iron-mines have given rise to varying methods of operation. Improvements and economies have been constantly introduced in consequence of competition among producers and cheapened prices for ore, until, at present, the mining cost is much below what it has ever been before, and many mines are to-day making records that a few years ago would have been deemed impossible. Thus, a few years ago (1890), the average mining cost of Lake Superior iron ore was not far from 5s. (\$1.25) per ton. In the year 1897, it cannot be more than 2s. 6d. (\$0.60) if the mining companies are to come out without a loss on the season's work at the prices that they themselves have established.

At none of the iron-mines have such great depths been attained as in the copper-mines of Michigan. The deepest iron-mine is about 1,200 feet deep, and that is not now in operation, while some of the copper-mines have a depth of 4,500 feet.

The mining methods which are in vogue on all but the Mesabi range are those which are necessary for underground mines; while on the latter range some of the largest mines are worked as open pits.

Owing to the irregular shapes of the ore-bodies, no two mines are planned and worked exactly alike. It is customary, however, to sink one or more shafts in the foot-wall and connect them with the ore by cross-cuts at different levels. The amount of ore hoisted through one shaft depends, of course, on the depth of the mine, size of the shaft, size of the skips or cages, etc.; but it also varies much with the general plan of development and operation of the mine, and runs as high as 60,000 tons per month. The shafts have from one to four compartments, and are equipped with round iron-wire hoisting-cables, and with cages or skips of from 3 to 10 tons capacity.

Much pumping is necessary at some mines, and, at others, none at all.

Timbering varies in quantity and cost with the size and shape of the ore-body and the methods of exploitation adopted. This item of cost, as well as that of powder for blasting, varies from nothing on the Mesabi range to several pence (cents) per ton in hard-ore mines.

Tramming is done by hand, by mules, and by electricity; and hoisting and pumping by steam and compressed air. Some celebrated plants are connected with these iron-mines, and are described in the various engineering transactions and journals. The general methods of working the old range mines require no particularly detailed description here; but more interest attaches to the Mesabi range.

The ingenuity and varied resources of the mining men of Lake Superior have never been put to severer tests than in the solution of the novel problems that have arisen on the Mesabi range, and it is high praise to say that these problems have been solved as fast as they have been encountered. The three methods that have been adopted for mining these flat deposits are:—(1) The steam-shovel method; (2) the milling method; and (3) the underground method.

(1.) The steam-shovel method has its ardent advocates and its strenuous opponents. It is claimed for this process on the one hand that the ore cannot be mined without mixing, and on the other that it cannot by any possibility produce a good mixture; that it cannot be used for more than two seasons, and that it is able to take out the ore clean to the bottom of the deposit; that only a few properties are adapted to it, and that it might be used even where a hundred-foot bed of ore is covered by a hundred feet of glacial drift. As usual the truth would be somewhere between these two extremes. There are five mines on the Mesabi range that are operated by steam-shovel, the Biwabik, Oliver, Ohio, Mountain, and Mahoning. These five mines produced about 50 per cent. of the output from this range in 1896, of which by far the largest amount came from the Oliver.

Figs. 8, 9, 10, 11, and 12 illustrate the steam-shovel method of mining iron ores.

Early estimates of the cost of mining by this process were ridiculed by many who were not familiar with the conditions existing on the Mesabi, or by those who were not disposed to recognize and admit the significance of these conditions. Although the cost at different mines varies with the depth of stripping, hardness of the ore, shape of ore-deposit, ease or difficulty of approach, quantity of ore produced and care required in mining, it frequently happens that a disadvantage at one mine is counterbalanced by an advantageous feature as compared with some other property, and with a given output the total mining costs may not be widely different at different mines. The writer has on former occasions, both in the *Iron Trade Review* and elsewhere, enumerated the factors going to make up this cost, and will not now again repeat them. Suffice it to say that the stripping charge per ton of ore uncovered does not usually exceed 3d. or 3½d. (6 or 7 cents) per ton for either this or the milling process (although it is said to have been as high as 8½d. (17 cents) at one mine worked by the latter method), and that the cost of shovelling ore out of



FIG. 8.—WEST CUT AT THE BIWABIK IRON-MINE, SHOWING STEAM-SHOVEL AND CARS
LOADING FROM FACE OF IRON ORE 60 FEET HIGH.

its natural bed after stripping does not exceed 5d. (10 cents), and with a very large output may be less than half this amount. Assuming an output of 200,000 tons, a fair figure for mining cost by the steam-shovel process is 7½d. (15 cents) per ton, or 10d. (20 cents) if all charges are included.

(2) The milling process, as now developed, is essentially new on the Mesabi range. From the foot of a shaft sunk at the edge of the ore-body drifts are run out under the ore, and vertical raises are put up through which the ore is shovelled and drawn down into tram-cars, which are then run to the shaft and dumped into skips. These skips are of various sizes up to 6 tons capacity, although the most common is half that size. In this system, the surface is stripped off as for steam-shovel mining, and the investment for plant may be taken as about the same in each case. If the tramming distance is great, mules are successfully employed underground in both this process and regular underground mining. The output per man runs as high as 20 or even 30 tons per diem for all men employed about the mine, and in cases of emergency may be almost double this amount for short runs. From this it is seen that the mining cost by the milling process may be made almost as low as by the steam-shovel. The mines worked by this method are the Adams, Auburn, and Norman.

Figs. 13 and 14 illustrate the milling process of mining iron ores.

There is no apparent reason why the ore mined cannot be taken from certain desired strata or mixed as wanted to produce a certain grade by either milling or steam-shovel process. At the Oliver mine, during the past season, mixing was done by the shovel, in the yard, and at the dock, and although numerous delays were thus caused, and the production would have been larger but for those delays, yet an output of 808,291 tons was made with three steam-shovels, one of which was idle about half the time.

One advantage of the steam-shovel method is ability to respond to any sudden demands for ore, and in fact practically unlimited capacity after the stripping is done. If one shovel cannot do the work, two, three, or more can be employed, and several tracks run in on the ore-body. On the other hand, a mine can be developed with reference to its entire exhaustion by the milling and underground systems, while new devices must sooner or later be resorted to at the steam-shovel mines,

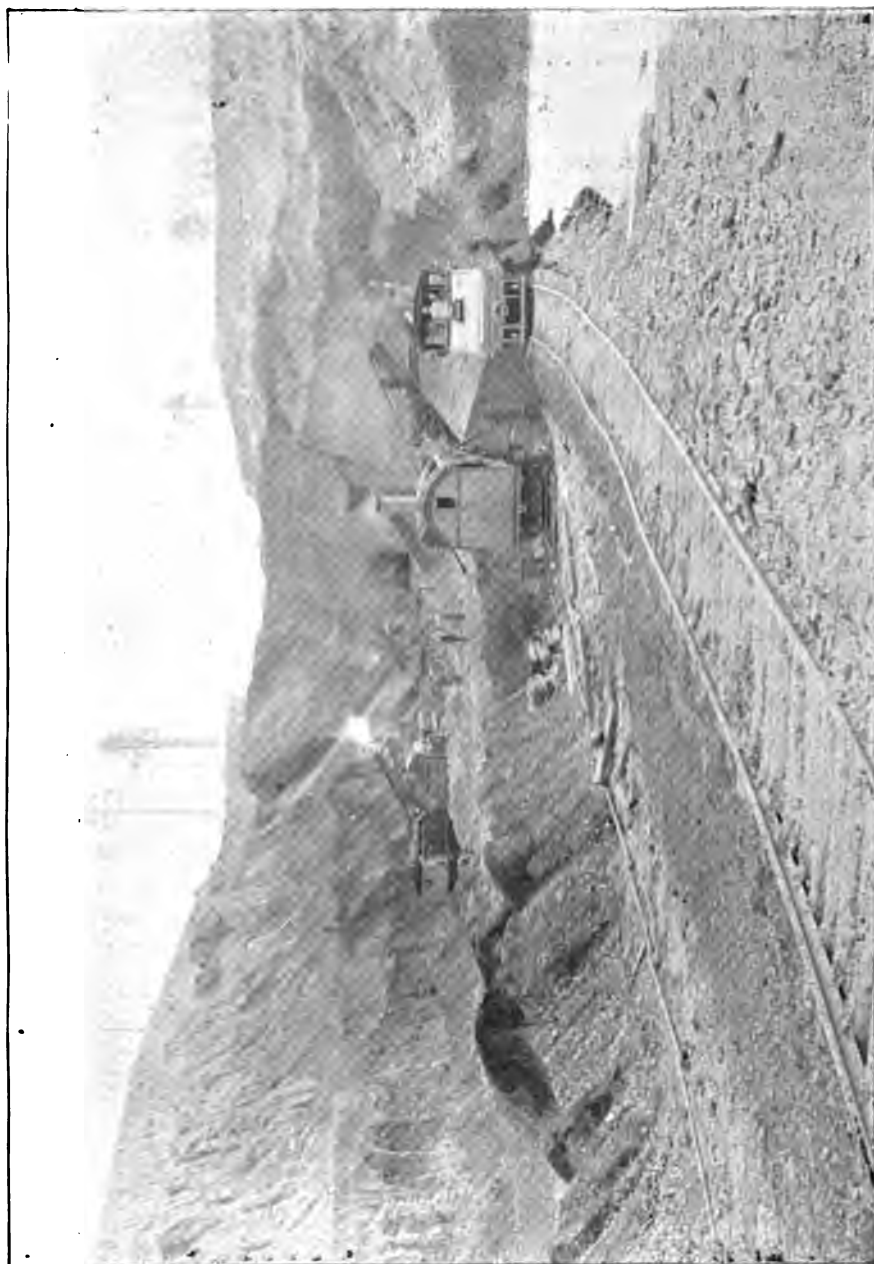


FIG. 9.—OLIVER IRON-MINE, SHOWING STEAM-SHOVELS AT WORK IN OPEN-CUT. THE FACE OF IRON ORE IN THE BACKGROUND IS NEARLY 100 FEET HIGH, AND THE CUT IS 1,500 FEET IN LENGTH.

(3) The underground method as adapted to the Mesabi range is still in process of development, and different systems will be found in different parts of the same mine. Square sets and various caving systems are seen, as well as a sort of slicing system similar to the longwall method of coal-mining. This underground mining is of course the most expensive, and is only employed where the ore is too deeply buried under glacial drift to permit of stripping. The underground mines are the Canton, Cincinnati, Genoa, Fayal, Vega, Franklin, Commodore, Minnewas, Sellers, and the Lake Superior mines at Hibbing. The output per man is from 4 to 5 tons (in specially favourable circumstances running up to 6 or 7) per day. The mining cost varies from 1s. 10½d. to 2s. 8½d. (45 to 65 cents) per ton, and with a small output or under unfavourable circumstances may be considerably higher.

After the ore is mined, it is dumped from the skip directly into cars or pockets for loading into cars during the shipping season. In the winter, the ore is put in stock-piles after being hoisted. It is, of course, unnecessary to work the open-pit mines during the winter. The advantages of the latter method are numerous. The work is done by daylight; men are in plain sight, and can be kept steadily at work, and directed more easily; there is less liability of accidents. The ore is handled but once, and the mine can be more easily planned for development.

The steam-shovels which are used in mining ore are of the largest size and the strongest patterns. They are calculated to load out of the natural bed from 4,000 to 5,000 tons in 10 hours without the aid of preliminary blasting. This has seldom been done, however, because of delays in furnishing cars. As soon as all arrangements are made, and a constant line of cars can be dropped down past the steam-shovel to receive their burden, these shovels may reach nearly their full capacity. Under such circumstances the ore will be mined for less than 2½d. (5 cents) per ton.

Chemical laboratories are maintained at most of the mines, and frequent analyses are made. In the underground mines, samples are taken in each stope, and out of the pockets or skips. In open-pit mines, samples are taken ahead of the shovel in the ore-bank, and from the cars. Frequently, a sample is made up from every 5 cars and analysed before the ore enters the vessel at the docks. Portions of these samples are retained until the cargo is sampled at the Lower Lake ports, and returns

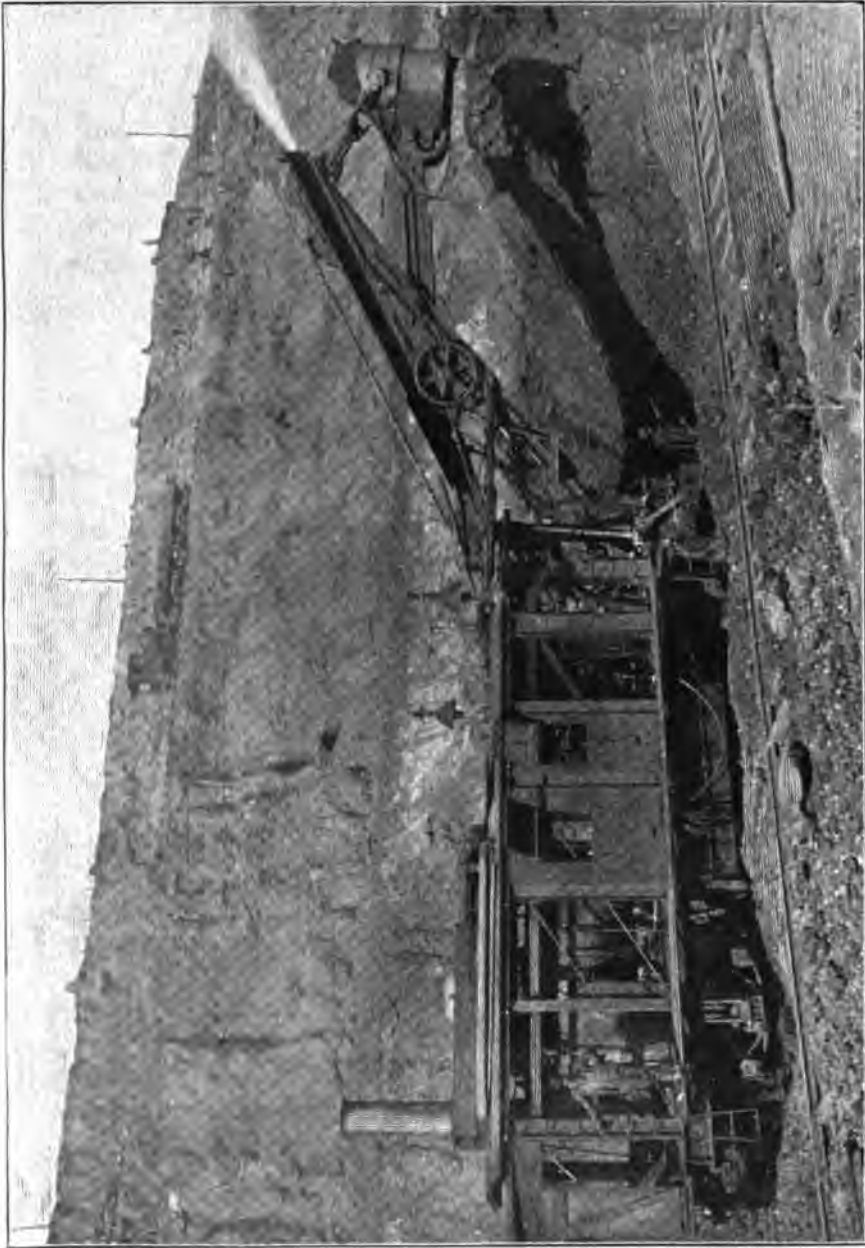


FIG. 10.—OLIVER IRON-MINE, SHOWING A FACE OF IRON ORE, 50 FEET HIGH, AND A 90 TONS STEAM-SHOVEL WITH A 2½ CUBIC YARDS DIGGER, CAPABLE OF LOADING 500 TONS OF ORE PER HOUR.

are received. At the end of the season, weighed portions of ore from each cargo are mixed together and subjected to complete analysis to give the season's average.

Labour costs are lower in the iron-mines than in the copper-mines ; surface-men and labourers receive about 4s. 7d. to 5s. (\$1.10 to \$1.25) per day. Miners get from 6s. 3d. to 8s. 4d. (\$1.50 to \$2) per day. Engineers and shovel-men get from £15 12s. 6d. to £31 5s. (\$75 to \$150) per month. The number of men employed in and around these iron-mines has exceeded 30,000. This number has been reduced lately, owing to the competition of machine-mined Mesabi ore.

As will be seen from the table of shipments, less time is required to make a producer of a Mesabi mine than of one on the other ranges. The result had shown some surprising figures for the first three years' production, and the establishment of records which have never been surpassed.

Thus the Biwabik mine produced 151,500 tons of ore during its first season. The Mountain iron-mine produced in the first year 119,818 tons ; in the second year, 573,440 tons ; and in the third year, 371,274 tons respectively ; a few tons having been shipped one year before for the purpose of furnishing samples of ore from the new range to the furnace-men. The Oliver mine yielded in the first year 123,015 tons ; second year, 505,955 tons ; third year, 500,377 tons ; and fourth year, 808,291 tons—a total of 1,937,688 gross tons from a property that was absolutely undreamed of until February or March, 1892. These are all open-pit mines ; but some of the underground mines have also made great records. Thus the Auburn produced 616,658 tons in three seasons ; the Franklin had a record of 787,525 tons in its first four years ; and the Adams produced 293,703 tons in its first two seasons. Even more surprising will be the figures for 1897 from some of these prolific mines.

QUALITY OF LAKE SUPERIOR IRON ORES.

The quality of these ores can best be indicated by a table of analyses (Appendix B). The names given in the list are the names of commercial grades as known to the trade, and are also frequently the names of the mines from which the ore comes. These analyses are the average in each case of the last season's shipments, usually for 1896, and have been obtained from the merchants who handle the ore, and other official sources. Taken together with the table of shipments, they exhibit the high grade and

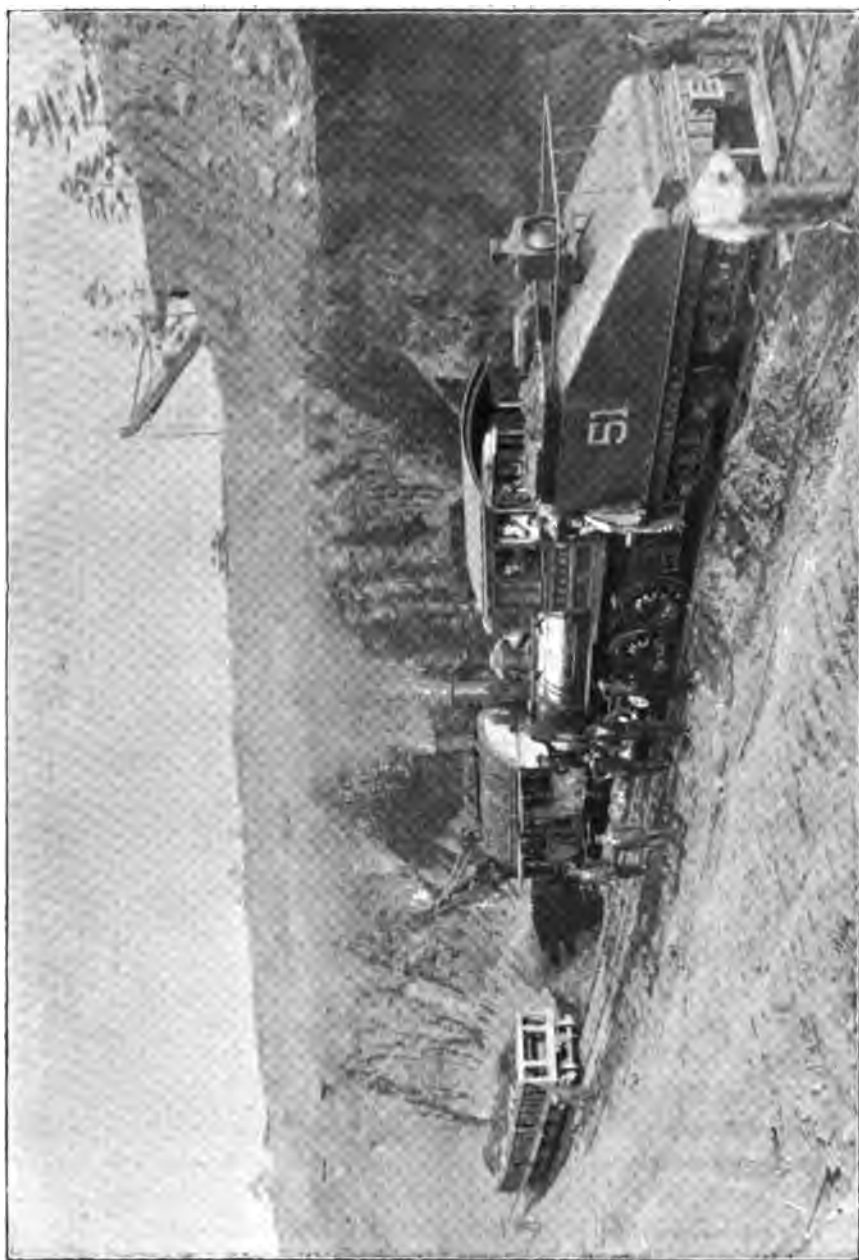


FIG. 11.—OHIO IRON-MINE, MESABI RANGE.

comparatively uniform character of the ore from this region as nothing else could show it. All ores are now sold on the basis of an assumed ore containing 63 per cent. of iron, 0·045 per cent. of phosphorus, and 10 per cent. of water. Hence the importance of the last column of figures in the table, under the heading "natural." The cost of transportation is to-day so large a proportion of the cost of ore laid down at Cleveland that the amount of moisture is carefully figured, and the value of the ore depends chiefly on the natural iron and the phosphorus.

TRANSPORTATION.

The iron ores from the different ranges are carried by rail and vessel to ports on Lakes Michigan and Erie, chiefly the latter, and there unloaded into railroad cars for further transport to the furnaces in Ohio and Pennsylvania, or piled up in receiving-docks and stored until sold during the winter or early spring. None of this ore is at present smelted in Minnesota, and but a nominal amount in Wisconsin and Michigan, owing to the entire absence of deposits of suitable coal. Charcoal iron to the amount of about 200,000 tons per annum represents the total pig-iron product of states which annually produce 10,000,000 gross tons of iron ore.

The distances traversed and the railroad rates charged per gross ton (2,240 pounds) from the mines to the Upper Lake ports are as follows :—

	Rate.		
	s.	d.	Dollars.
From Marquette range east of Republic and Michigamme to Escanaba, distance not over 65 miles ...	2	2	0·52
From Marquette range at Republic and Michigamme to Escanaba, distance 88 miles	2	9½	0·67
From Marquette range to Marquette, 15 miles ...	1	4	0·32
From Marquette range to Gladstone, 60 to 130 miles	2	2	0·52
From Menominee range east of Mastodon to Escanaba, maximum distance 52 miles	2	2	0·52
From Menominee range west of Mastodon (Crystal Falls), distance 82 miles	2	4½	0·57
From Gogebic range to Ashland, distance about 45 miles	2	2	0·52
From Gogebic range to Escanaba, distance about 184 miles	4	0½	0·97
From Vermilion range to Two Harbors, distance 68 to 90 miles	4	2	1·00
From Mesabi range to Duluth and Superior, about 75 miles	3	4	0·80

The sailing distances and average ton rates for ten years, 1886-1895, are as follows :—



FIG. 12.—MAHONING IRON-MINE, SHOWING STEAM-SHOVELS MINING ORE AND STRIPPING.

	Miles.	Contract Rate.			Wild Rate.		
		s.	d.	Dollars.	s.	d.	Dollars.
Marquette to Cleveland...	583	4	6½	1·09	4	8	1·12
Escanaba „ „ ...	523	3	9½	0·91	3	9½	0·915
Duluth „ „ ...	823	4	11½	1·19	5	5	1·30
Ashland „ „ ...	774	4	11½	1·19	5	5	1·30
Escanaba to Chicago ...	192	—	—	—	—	—	—

The average contract rates for the season of 1895 were :—

	s.	d.	Dollars.
Escanaba to Lake Erie ports ...	2	3½	0·55
Marquette „ „ ...	3	1½	0·75
Ashland and Duluth to Lake Erie ports	3	4	0·80

From this statement it may be seen that there has been a great reduction in vessel charges in recent years. In spite of this fact, however, the cost of transportation is to-day a larger part of the cost of the ore in Cleveland than it has ever been.

This freight, and a great deal more, all passes through the canal and locks at Sault Ste Marie, one of the busiest spots on the globe during the season of navigation. During the year 1895, the tonnage passed through the Manchester ship canal was but one-tenth of that which passed through the "Soo." (Figs. 15 and 16). During the same year, navigation was open from April 25th to December 11th, and in this time 17,956 vessels passed these locks, the registered tonnage of which aggregated 16,806,781 tons, and the value of whose freight was £33,244,818 (\$159,575,129). There are at present 3,300 vessels (1,755 steam) on the Great Lakes, with a total registered tonnage of 1,250,000 tons. Many of these vessels are of 4,000 tons burden, and exceed 400 feet in length. The loads which they carry vary from 4,000 or 4,400 gross tons on a draught of 14 or 15 feet to 6,000 tons on a 20 feet draught.

The speed with which these vessels are loaded and unloaded is one of the marvels of the day. The record of the steamer "Victory" may be mentioned in this connexion.* It is a vessel 400 feet long and of 48 feet beam, with a carrying capacity on 15 feet draught of 4,000 tons. It was loaded with coal at Lake Erie port in 10 hours. At Superior, this coal was discharged in 15 hours and a new cargo of iron-ore taken on in 5 hours, at the rate of 800 tons per hour. Arrived at a Lower Lake port this ore was unloaded on to cars at the rate of 560 tons per hour.

On Lakes Superior and Michigan, there are to-day 23 shipping docks with 4,624 pockets, of an aggregate capacity of 633,808 gross tons. When the pockets of the loading-docks are filled with the ore desired, it is not an uncommon occurrence for a vessel to tie up, load, and depart

* Mr. John Birkinbine, *Cassier's Magazine*, April, 1897, page 494.

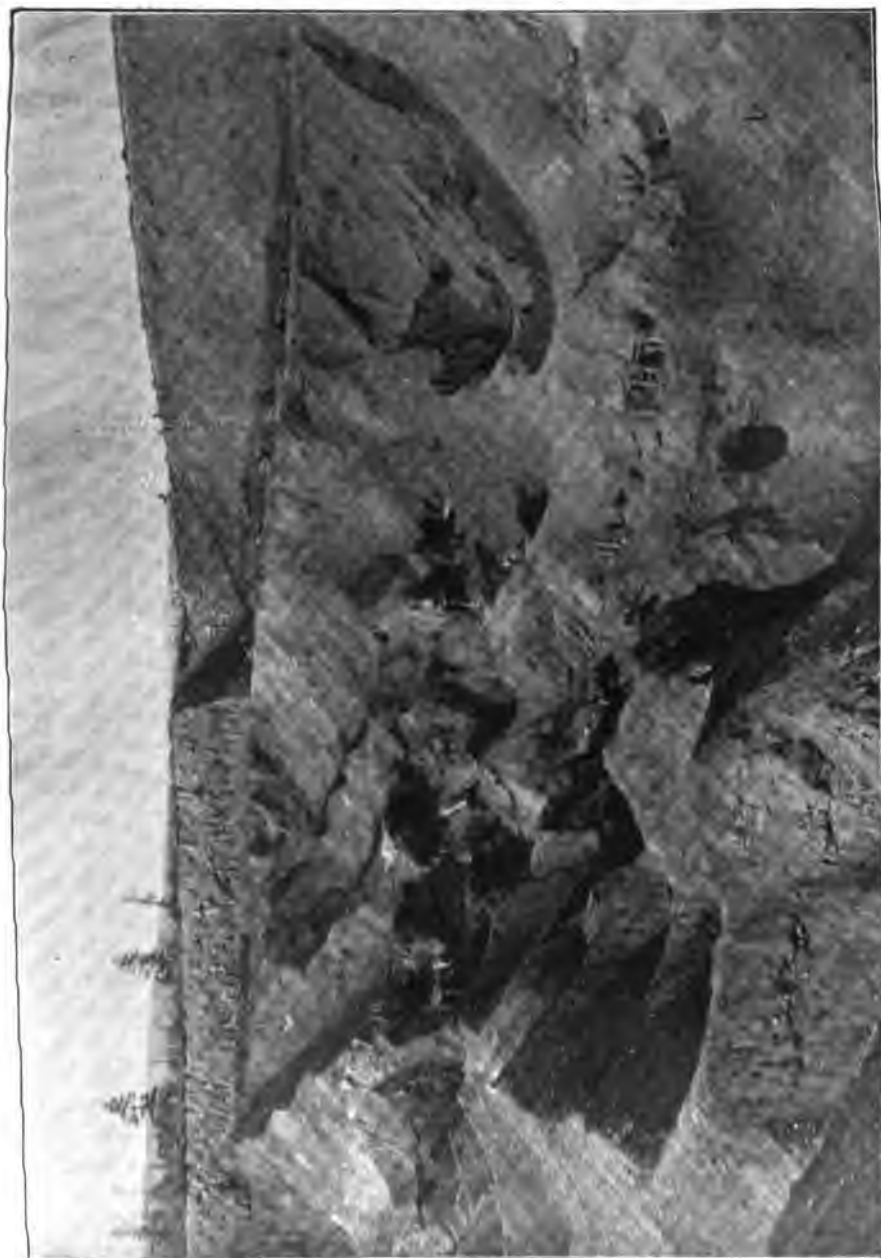


FIG. 13.—AUBURN IRON-MINE, WORKED BY THE STRIPPING AND MILLING SYSTEM.

within 2 hours. (Figs. 17 and 18). One record has been made of 2,350 tons of ore loaded in $\frac{3}{4}$ hour. The capacity of ore-carrying vessels has recently been largely increased, as is related in the following extract from the *Bulletin of the American Iron and Steel Association*.:—*

Never before in the history of American shipbuilding has such work been seen as has been done in the construction of the Bessemer Steamship Company's fleet of lake-freight ships. About the close of the first week in December last the company was formed, and its Cleveland agents made contracts with lake shipyards, all then fairly full of work, for the building of 12 great ships, each to be larger than anything on the lakes, with the exception of 1 steamer afloat and 2 under contract for the Zenith Transportation Company of this city. The end of this week sees 7 of these ships in commission, while 1 more will be set at work about September 20th, and the remaining 4 will be ready in October. In addition 4 ships have been purchased, and the fleet as it will be before the close of the coming month—less than 10 months after the decision to build was made—will have a capacity for carrying the enormous quantity of 65,000 tons on present and 95,000 tons on the coming deeper draught. These ships have cost about £708,333 (\$3,400 000).

The Bessemer Steamship Company was the outgrowth of the control by Mr. John D. Rockefeller of the mines formerly under the Merritt ownership on the Mesabi range and of the railway between those mines and Duluth. Mr. Rockefeller reasoned that, owning both the mines and the railway to the water, he should control as well the transportation of the ore to the Lower Lakes. To decide was to act, and one of the most important fleets in American waters, salt or fresh, was completed in less than a year. It was proposed that this fleet should be able to handle the output of the mines, and as planned they will be able to carry about 2,000,000 tons in one season.

The contracts for the Bessemer fleet filled all the lake yards with tonnage till about the middle of the spring, when the boats began to slip into the water. Since then there have been no contracts made, and with the completion of the last of these ships nine great shipyards along the lakes will be idle, with no business in sight. This is a condition that has not prevailed for many years, for even in the panic of 1893 there was business for some of the yards. Many thousands of men will then be out of work.

The vessels of the Bessemer fleet have been appropriately named after men famous for their connexion with the mining, engineering, and metallurgical world. The flagship of the fleet is the "Sir Henry Bessemer," while among the others are such names as "Nasmyth," from the inventor of the steam hammer; "Ericsson," from the builder of the "Monitor;" "Corliss," the maker of engines; "Krupp," "Fulton," "Watts," "Siemens," "Bell," "Fairbairn," and "Holley." Amid all the development of the lake marine and steel interests in the last few years it has strangely enough remained for this new company to honour the memories of the greatest men these industries have had by naming ships after them. The "Bessemer," "Siemens," "Fairbairn," and "Ericsson," and the barge "Holley" are now in commission, and each one has carried loads enough to test its capacity. They were all built on a guarantee by the constructors of a capacity, on 14 feet draught, of 4,000 gross, or 4,480 net, tons. Each has slightly exceeded these figures. Were these vessels operated on the draught of water for which they were built they would be able to carry between

* October 1st, 1896.



FIG. 14.—NORMAN IRON-MINE, WORKED BY THE STRIPPING AND MILLING SYSTEM.

6,500 and 7,000 tons each, and they will be able to use nearly this depth of water by the beginning of another season, when the government's 21 feet channel between Duluth, Chicago, and Buffalo will have been completed.

The cost of unloading ore from the vessels has been much reduced in late years by the construction of unloading devices which take the ore after it is loaded into buckets and automatically carry it to the stockpile, dump it and return it for a new load (Fig. 19). This cost is now only $\frac{1}{4}$ d. or $\frac{3}{4}$ d. (1 or $1\frac{1}{2}$ cents) per ton.

The railroad equipment of the ore-carrying roads compares in size and efficiency with that employed in marine traffic. The roads are standard gauge. The rails are heavy and of large section, weighing 80 or 90 pounds to the lineal yard. The locomotives are among the most powerful ever built, weighing from 80 to 120 tons, and hauling trains of from 30 to 50 cars carrying 750 to 1,250 gross tons of ore at an average speed of 17 miles per hour including stops. Some of the roads are double-tracked and others will be soon.

The amount of capital invested in Lake Superior iron-mining has been estimated as follows by Mr. George H. Ely and the Lake Carriers' Association of Cleveland, Ohio. These data were compiled as largely as possible from official sources and were presented in a statement to the Congress of the United States:—

Capital in the mines of the four iron-ore ranges, as shown by the United States census and estimates since last census was taken ...	£	Dollars.
Capital in docks and their equipment at Lake Superior and Lake Michigan ports, built and used exclusively for shipping iron ore (official)	20,067,734	96,325,122
Capital employed exclusively in railroad trans- portation of iron ore, from mines to ship- ping ports on Lakes Superior and Michigan (official)	2,955,347	14,185,665
Floating capital on the lakes, employed exclu- sively in ore-transportation from Upper Lake to Lower Lake ports, estimated ...	6,742,624	32,364,594
Capital in docks and in their equipments for receiving and forwarding iron ore exclu- sively, at Lake Erie ports between Toledo and Buffalo, inclusive of both (official) ...	9,725,043	46,680,207
Capital employed exclusively in rail-transpor- tation of iron ore, inland to mills and furnaces from Lake Erie ports (official) ...	3,227,683	15,492,880
	5,873,670	28,193,617
Total, January 1st, 1896... ..	£48,592,101	\$233,242,085

The year which has passed since the preparation of the above table has witnessed the construction of the large fleet of vessels owned by Mr. Rockefeller, the new iron-ore railroad in Pennsylvania owned by Mr. Carnegie, the railroad between Ishpeming and Marquette, and improvements and extensions of docks and railroad and mine-equipments in all directions, so that it is probably not an exaggerated estimate to place the amount of capital invested in Lake Superior iron-mining at £50,000,000 (\$250,000,000).



FIG. 15.—U.S. GOVERNMENT VESSELS MAKING THE FIRST PASSAGE THROUGH THE COMPLETED NEW LOCK OF THE SAULT SAINTE MARIE CANAL CONNECTING LAKES SUPERIOR AND HURON.

MARKET PRICES OF IRON ORES.

As one after another of the great Lake Superior iron-ore ranges has been discovered and developed, and as methods of mining and handling the ore have improved in efficiency and detail, prices have reached lower and lower levels; the margin between cost of production and selling price has constantly narrowed and earnings have been made on larger outputs and greater economy of operation. The discovery of the immense Mesabi deposits of soft ore, so much more cheaply mined than the hard ores has, however, had a much greater effect on prices of iron-ore and of iron and steel than any of the former discoveries. When prices were high and less ore was used very little account was taken of

its exact composition and value. If a furnace ran well on a certain ore, the managers of that plant would purchase that ore year after year, even though they could get some other ore equally as good at a somewhat lower price. As competition among ore-producers became fiercer however, and furnace-operators found it necessary to economize in their costs, the relative values of the different ores have been more and more closely



FIG. 16.—WHALEBACK STEAMER ENTERING LOCK OF THE SAULT
SAINTE MARIE CANAL.

scrutinized and made the basis of market prices until they have reached the point where quotations are in fractions of $\frac{1}{2}$ d. (1 cent) per ton, and the older ranges have all combined against the prolific Mesabi range, forcing prices down to so low a rate that very few producers on any of the ranges can make any profits.

The prices have ranged somewhat as follows in former years :—

BESSEMER ORE.

Year.	Price.			Year.	Price.					
	s.	d.	Dols.		s.	d.	s.	d.	Dols.	Dols.
1856 ...	33	4	8·00	1888			22	11		5·50
1866 ...	39	7	9·50	1889			22	11		5·50
1868 ...	40	7½	9·75	1890			28	1½		6·75
1873 ...	50	0	12·00	1891			25	0		6·00
1876 ...	28	1½	6·75	1892			22	11		5·50
1881 ...	37	6	9·00	1893	16	8	to 18	9	4·00	to 4·50
1886 ...	22	11	5·50	1894	10	5	to 11	5½	2·50	to 2·75
1887 ...	30	2½	7·25	1895	11	5½	to 14	7	2·75	to 3·50

NON-BESSEMER ORE.

1890 ...	23	11½	5·75	1893	12	6	to 14	7	3·00	to 3·50
1891 ...	19	9½	4·75	1894	7	6	to 9	2	1·80	to 2·20
1892 ...	17	8½	4·25	1895	7	11	to 9	2	1·90	to 2·20

These prices are for the ore delivered at Cleveland or any designated Lower Lake port. The ore is sold on guarantee as to quality, and is sampled and analysed at the mines and at the receiving-docks. A few illustrations of the way in which prices have ruled on some representative ores during the past three years, including the prices established for 1897, are as follows:—

Ore.	1895.			1896.			1897.		
	s.	d.	Dollars.	s.	d.	Dollars.	s.	d.	Dollars.
Aurora ...	12	6	3·00	17	3½	4·15	11	8	2·80
Biwabik ...	11	0½	2·65	15	2½	3·65	10	5	2·50
Chandler ...	12	8½	3·05	17	8½	4·25	12	2½	2·925
Chapin ...	10	7½	2·55	15	2½	3·65	10	0	2·40
Fayal ...	9	4½	2·25	—	—	—	10	0	2·40
Franklin ...	11	5½	2·75	15	7½	3·75	10	7½	2·55
Lake Angeline...	14	9½	3·55	20	5	4·90	14	5	3·46
Minnesota ...	14	2	3·40	18	11½	4·55	12	11	3·11
Non-Bessemer ...	—	—	—	11	0½	2·65	9	4½	2·25
Norrie ...	12	1	2·90	16	8	4·00	11	0½	2·65
Pewabic ...	14	9½	3·55	20	5	4·90	14	2	3·40
Pioneer ...	12	8½	3·05	17	8½	4·25	11	11½	2·87
Republic ...	13	9	3·30	18	11½	4·55	13	2½	3·17
Tilden ...	12	1	2·90	16	8	4·00	10	8	2·56

During 1896, prices were maintained at a high level through the agency of an ore-pool or general agreement among the principal producers. It was found impossible to make satisfactory allotments to all parties for 1897 however, owing to dissatisfaction with the operation of the arrangement in the previous year, and the only agreement which now exists is one among the producers of the three Michigan and the Vermilion ranges.

As the question of price is a very important one and has more than a local effect since the United States have begun to export iron and steel, it seems worth while to quote verbatim an editorial article, showing how the price of Bessemer iron ores from the Lake Superior ranges is established for the year 1897. The price of Mesabi ores for this year is variable, and has been fixed, so far as it is definitely established, at about 1s. 0½d. (25 cents) per ton less than for ores of similar chemical composition from the other ranges. The differential against Mesabi ores is justified on the ground that it can be so much more cheaply produced,



FIG. 17.—IRON-ORE LOADING DOCKS AT TWO HARBOURS, MINNESOTA.

and it is sustained because there has been some slight difficulty in working these ores in the furnaces which have always heretofore run on coarser ores. This differential, by offering its own inducement to the consumer who wishes to get his ore cheaper, is working itself out, and diminishing from year to year, and will sooner or later entirely disappear.

The editorial article is as follows :—

It was indicated in these columns last week that the prices for Lake Superior Bessemer ores of the Marquette, Menominee, Gogebic, and Vermilion ranges, as established for 1897, were the result of the closest computation, the design being to arrive at a schedule exactly representing the relative values of the various ores. It was stated that while in other years a difference of a few cents between ores of

substantially the same composition was not considered reason enough to split a half-dime in making up a schedule, this year's price-list, in two or three instances, introduced a half cent, in the effort to give each ore its exact place, as determined by its composition. In this connexion, a more detailed statement of the method followed in computing prices will be interesting.

The decision having been arrived at that Norrie ore would be sold at 11s. 0½d. (\$2.65) laid down at Lake Erie dock, and that the base should be a supposititious ore containing 63 per cent. of iron, 0.045 per cent. of phosphorus and 10 per cent. of natural moisture, the groundwork was furnished. With Norrie at 11s. 0½d. (\$2.65), the base ore figured out 10s. 10d. (\$2.60). But the problem that involved days of conference and computation was to express fairly the actual relative value to the furnaceman of the 45 or 50 ores in the list, so that each should stand in the list just where it would go as a component of the resulting pig-iron, with the



FIG. 18.—LOADING IRON ORE AT ASHLAND, WISCONSIN.

furnaceman's sharpest pencil figuring on the mixture. The procedure adopted in getting the basis of a formula, really involved taking the ore into the Mahoning or Shenango valley, as a midway point between the lake shore and Pittsburg, determining its value in the pig there, and then deducting the freight into the valley to get the price on Lake Erie dock, which has been the usual basis of sales. The fact that moisture figures as a considerable element in freight cost, accounts for basing the price-computations on the dried ore at a furnace intermediate between those on the lake shore and those at Pittsburg.

Taking, now, the base ore at 10s. 10d. (\$2.60), the average freight to a valley furnace, presuming that half the consumer's supply went forward direct from vessel and half was taken from dock stock-piles, would be 2s. 3½d. (55 cents), counting 2s. 3¾d. (55½ cents) net for direct ore and 2s. 4¾d. (57½ cents) net for stockpile ore. This gives 13s. 1½d. (\$3.15) as the price in the valley. Divided by 56.70, the iron

content of the ore dried at 212° Fahr. gives 2.7775d. (\$0.05555) as the unit price of all ores in the list, taking no account of phosphorus. Thus the dock value of an ore running 65 per cent. in iron, having 6 per cent. of moisture and the same phosphorus content as the base ore—0.045 per cent.—would be found by multiplying 61.10 by 2.7775d. (\$0.05555) and deducting from the product 14s. 1½d. (\$3.39) the 2s. 3½d. (55 cents) average freight, giving 11s. 10d. (\$2.84).

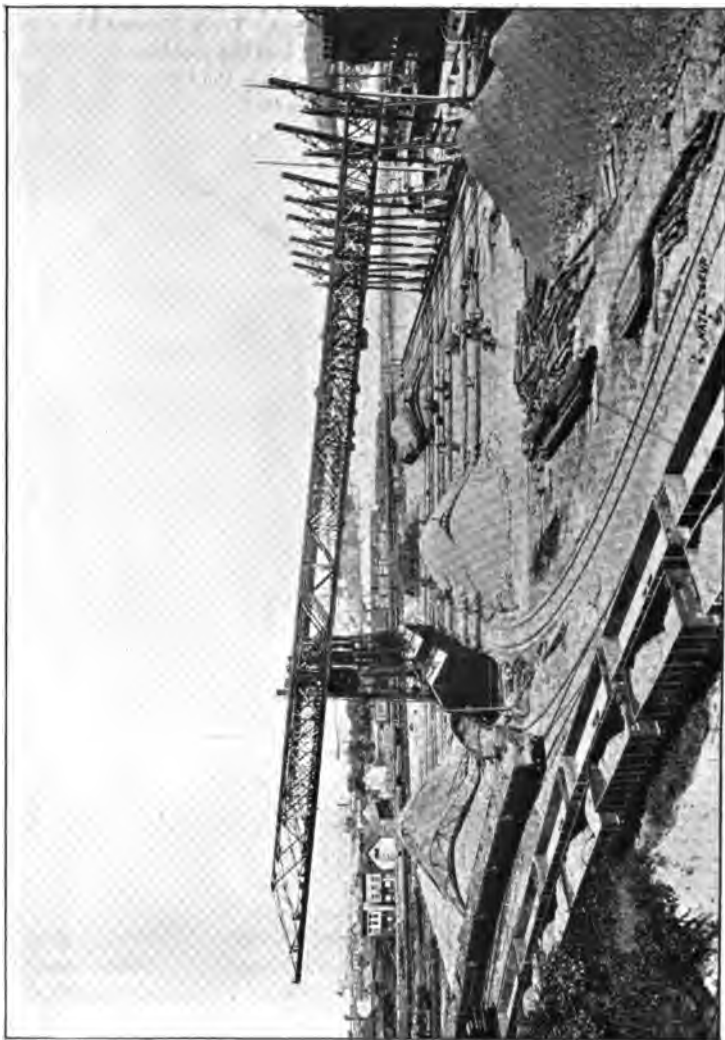


FIG. 19.—HOIST AND CONVEYOR FOR UNLOADING IRON-ORE VESSELS, ASHTABULA, OHIO.

The variations in phosphorus introduced another complication ; and the result of the work on this part of the problem is the phosphorus table given below, which is a conspicuous feature of the labours of the new association in the direction of a scientific basis of values.

The starting-point in the computation of phosphorus values was established at 0.375d. ($\frac{1}{4}$ cent), and the rates of increase in the price for lower phosphorus were made to vary by 0.025d. (\$0.0005, or one-half mil) for a phosphorus variation of 0.001 per cent. The addition to be made to the price of an ore because of its lower phosphorus will be found by adding together the various increments opposite the phosphorus percentages intervening between the base and the percentage in question, and then adding the increments of the latter. Thus an ore running 0.042 in phosphorus would be worth, on account of its lower phosphorus, 1.275d. (2.55 cents) more than the base ore, or the sum of 0.4d. (\$0.0080), 0.425d. (\$0.0085) and 0.45d. (\$0.0090), these being the increments or rates of progression opposite 0.044, 0.043 and 0.042. An ore 0.070 in phosphorus, the table shows, would be worth 1s. 5½d. (35 cents) less than the base ore; an ore 0.020 in phosphorus, 1s. 5½d. (35 cents) more than the base ore, and an ore 0.005 in phosphorus, 2s. 11½d. (71 cents) more than the base ore. Adding together the extremes of the table, there would be a difference of 4s. 5d. (\$1.06), based solely on phosphorus, between an ore containing 0.07 per cent. and one containing 0.005 per cent. of that element. The 0.07 ore is of course beyond the Bessemer limit, but the figure is carried over, apparently, from the preceding season, when Mesabi ores of that constituency were included in the allotment because they found their way into certain Bessemer mixtures.

PHOSPHORUS TABLE.

Per-cent- age.	Rate of Pro- gression.	Phos. Values.	Per-cent- age.	Rate of Pro- gression.	Phos. Values.	Per-cent- age.	Rate of Pro- gression.	Phos. Values.
	Dollars.	Dollars.		Dollars.	Dollars.		Dollars.	Dollars.
0.070	0.0200	0.3500	0.048	0.0090	0.0255	0.026	0.0170	0.2375
0.069	0.0195	0.3300	0.047	0.0085	0.0165	0.025	0.0175	0.2550
0.068	0.0190	0.3105	0.046	0.0080	0.0080	0.024	0.0180	0.2730
0.067	0.0185	0.2915	*0.045	*0.0075	*0.0075	0.023	0.0185	0.2915
0.066	0.0180	0.2730	0.044	0.0080	0.0080	0.022	0.0190	0.3105
0.065	0.0175	0.2550	0.043	0.0085	0.0165	0.021	0.0195	0.3300
0.064	0.0170	0.2375	0.042	0.0090	0.0255	0.020	0.0200	0.3500
0.063	0.0165	0.2205	0.041	0.0095	0.0350	0.019	0.0205	0.3705
0.062	0.0160	0.2040	0.040	0.0100	0.0450	0.018	0.0210	0.3915
0.061	0.0155	0.1880	0.039	0.0105	0.0555	0.017	0.0215	0.4130
0.060	0.0150	0.1725	0.038	0.0110	0.0665	0.016	0.0220	0.4350
0.059	0.0145	0.1575	0.037	0.0115	0.0780	0.015	0.0225	0.4575
0.058	0.0140	0.1430	0.036	0.0120	0.0900	0.014	0.0230	0.4805
0.057	0.0135	0.1290	0.035	0.0125	0.1025	0.013	0.0235	0.5040
0.056	0.0130	0.1155	0.034	0.0130	0.1155	0.012	0.0240	0.5280
0.055	0.0125	0.1025	0.033	0.0135	0.1290	0.011	0.0245	0.5525
0.054	0.0120	0.0900	0.032	0.0140	0.1430	0.010	0.0250	0.5775
0.053	0.0115	0.0780	0.031	0.0145	0.1575	0.009	0.0255	0.6030
0.052	0.0110	0.0665	0.030	0.0150	0.1725	0.008	0.0260	0.6290
0.051	0.0105	0.0555	0.029	0.0155	0.1880	0.007	0.0265	0.6555
0.050	0.0100	0.0450	0.028	0.0160	0.2040	0.006	0.0270	0.6825
0.049	0.0095	0.0350	0.027	0.0165	0.2205	0.005	0.0275	0.7100

* Base.

The figures above and the accompanying data would indicate the utmost painstaking in the preparation of the new Bessemer ore-schedule; and the appearance of odd cents and even half cents in a list of ore-prices is another index to the new era, in which cost is figured, not in dollars, nor even in fractions of dollars, but down to the ultimate cent.*

* *The Iron Trade Review*, 1897.

CONCLUSION.

Having given thus briefly and imperfectly a description of the greatest iron-ore districts of the world to-day, the question of future development and operation naturally arises. How long can these mines supply the constantly increasing demand? When will the limit of economy and capacity for great production be reached, and what will be the result on the iron markets of the world? We may suggest in a few words the solution of some of these problems.

It is frequently stated on good authority that the Bessemer-ore supply of the Lake Superior region outside of the Mesabi range is not more than enough for 5 years' production. It is a fact, however, that more development work is required to open up underground mines, and that even a 5 years' supply in sight is an indication of liberal and progressive mining methods. More ore is constantly being discovered. New mines are being developed, and mines that are supposed to be exhausted spring into new activity, producing as good ore as ever, and much more cheaply.

Granting that there is a limit to the amount of ore contained in these rocky storehouses, and admitting that the present rate of consumption is enormous, still the day is yet a long way off when the underground and hard-ore mines of this region will cease to respond to the demands of ever-widening civilization and its ever-increasing use for iron.

Turning now to the Mesabi range, we are still more reassured as to the permanency of our industry and the stability of low iron costs. When this range was first developed, the miners and merchants of the other districts comforted themselves with the vain hope that "the Mesabi range was pockety," "its shallow mines would soon be exhausted," "its ores could only be used in very small quantity in average mixtures," etc. The facts are these:

There is more ore in sight to-day, three or four times over, than the whole Lake Superior region has produced in half a century. Its deposits are deeper, wider, longer, better than those of any other range. More of its ore has been used for two years past than of ore from any of the older ranges, and in 1897 the majority will be much greater.

Here is a district in which active exploration dates back but 5 years, and which has been a producer but 4 seasons, and yet which has in sight to-day nearly 400,000,000 gross tons of better ore than the average used in the United States, and perhaps 200,000,000 tons that will average 60 per cent. of iron, 0.060 per cent. of phosphorus, and 10 per cent. of

moisture, and the end is not yet. It is not by any means a wild prediction that the Mesabi range will produce 500,000,000 tons of iron ore before it is abandoned.

It is perhaps not to be expected that a much lower cost of mining can be attained, although it is unlikely that the bottom has yet been reached. Fee owners at present receive royalties of from 5d. to 1s. 5½d. (10 to 35 cents) per ton from the mining companies which hold leases. These royalties are in many instances excessive, and are undergoing gradual reduction. Lake and railroad charges are in most cases higher than they ought to be, and are also being reduced, some such announcements having already been made for 1897. Commission merchants still charge from 2½d. to 5d. (5 to 10 cents) per ton for selling the ore, regardless of the fact that more ore is sold and that the market price and margin to the producer is much lower than formerly. These commissions are being eliminated through the purchase of mines by furnace-companies who operate them for their own use, in some instances also hauling the ore in their own vessels and railway-cars.

Even mining costs are constantly growing less. The main reason for this in the future will lie in combination and enlarged operation under few managements. By this means the labour cost is not so much reduced, but fixed charges are distributed over a larger tonnage and the cost per ton is lessened. It is natural to expect also that better results will be obtained on the Mesabi range as more experience is gained and the best methods are ascertained. At present, the cost of a ton of iron-ore laid down at Lake Erie dock is made up of the following items:—

	s.	d.		s.	d.	Dollars.	Dollars.
Royalty	0	0	to	1	5½	0·00	to 0·35
Mining cost	0	7½	to	3	1½	0·15	to 0·75
Rail freight	1	4	to	4	2	0·32	to 1·00
Lake freight	2	6	to	3	4	0·60	to 0·80
Insurance commission and loss	0	2½	to	0	10	0·05	to 0·20
Totals	4	8	to	12	11	1·12	to 3·10

There is probably no mine which has all the minimum costs, and several which cannot sell ore at a profit at 12s. 11d. (\$3·10) per ton. It is evident, however, that prices may go still lower without shutting up enough mines to produce a scarcity of ore.

One effect of this cheap ore has already been seen in lower prices for iron and steel. And, if still lower prices be possible, the prospect is good for exporting iron and steel in large quantity from furnaces which turn

out as much in a day as many foreign plants do in a week, on a consumption of 1,600 pounds of cheap coke per ton of metal.

That our exports have begun is known to all. That they are not a result alone of depressed conditions in the United States, but of the lower cost-sheets, developed as a consequence of enforced economy on the one hand and of the great discoveries of cheaply-won ore and increased efficiency and size of ore-handling and iron-making plants on the other hand, is perhaps not so generally realized. The author firmly believes that the United States has entered the foreign field to stay, and that her advantages are such as to enable her to do a profitable business in iron at lower rates than have ever been quoted.

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APPENDIX B.—IRON ORE ANALYSES. SHIPMENTS OF 1896.*

MARQUETTE RANGE.

Trade Name of Grade.	Iron.	Silica.	Phos- phorus.	Man- ganese.	Alu- minum.	Lime.	Mag- nesium.	Sul- phur.	Mole- ture.	Volatile Matter.	Natural
Barnum	65.50	8.49	0.075	0.36	1.79	0.33	0.26	0.036	11.02	—	58.39
Beacon	46.00	29.75	0.048	0.07	2.50	1.00	0.80	0.080	0.84	—	45.45
Bess. Old Mine, Hem. ..	68.00	3.23	0.065	0.65	1.80	0.42	0.21	0.011	9.75	—	56.54
Blue	63.40	5.20	0.118	0.25	1.96	0.55	0.72	0.010	10.55	1.80	56.71
Buffalo	61.80	6.60	0.127	0.55	1.84	0.88	1.16	0.003	10.70	2.10	55.18
Cambrisa	61.40	6.90	0.046	0.34	1.92	0.74	0.30	0.012	10.10	1.65	55.23
Champion, No. 1	63.92	3.80	0.048	0.07	1.70	0.75	0.55	0.005	0.80	—	63.41
Cleveland, Bessemer ..	67.23	2.75	0.044	0.11	0.20	0.25	0.24	0.017	0.84	—	66.68
Cliffs Shaft	69.42	8.65	0.118	0.85	1.70	1.15	1.00	0.030	1.06	—	41.79
Columbia	56.13	8.20	0.55	0.06	1.46	1.55	0.06	—	10.77	—	52.51
East End, Bessemer ..	61.06	7.48	0.046	0.23	2.09	0.23	0.80	0.014	10.33	—	54.75
Essex	60.00	10.25	0.110	0.20	2.20	0.63	0.20	0.030	0.74	—	59.25
Foster	51.45	18.45	0.142	0.27	1.10	0.18	0.39	0.020	3.63	—	49.18
Foster, Silica	49.00	27.00	0.122	3.86	1.36	0.20	3.87	0.002	3.00	—	40.74
Harvard, Bessemer ..	66.23	2.85	0.049	0.67	1.70	0.47	0.25	0.018	14.50	—	56.60
Humboldt	65.90	8.91	0.15	0.13	1.88	0.88	0.24	0.020	—	—	—
Ishpeming	67.41	10.25	0.072	0.57	2.62	0.38	0.36	0.030	9.89	—	51.63
Jackson, South Side ..	48.97	80.81	0.05	2.12	2.00	—	—	—	—	—	—
Jackson, Pitt No. 7 ..	67.77	11.00	0.068	2.15	2.00	—	—	—	—	—	—
Lake	60.85	5.67	0.088	0.60	2.10	0.41	0.32	0.018	12.10	—	53.55
Lake Angeline	68.03	—	0.042	—	—	—	—	—	—	—	8.69
Lake Angeline, Hard ..	66.19	—	0.014	—	—	—	—	—	—	—	3.99
Lake Bessemer, No. 1 ..	65.44	5.50	0.030	—	1.40	—	—	—	9.97	—	58.92
Lake Bessemer, No. 2 ..	64.01	5.50	0.038	0.24	1.40	0.95	0.21	0.019	9.63	—	57.55
Lake Silica	48.27	25.40	0.042	0.48	1.69	0.36	0.47	0.055	9.07	—	48.92
Lake Superior, No. 1 ..	65.00	8.40	0.100	0.23	2.10	0.26	0.24	0.018	1.15	—	64.25
Lille	61.75	5.60	0.077	0.39	1.92	0.37	0.08	0.010	9.60	2.79	55.31
Marquette	43.50	34.10	0.510	0.26	0.97	0.17	0.17	0.021	6.12	—	40.84
Michigamme	66.50	4.67	0.18	0.23	0.07	0.26	0.62	0.060	0.72	—	66.00
Missabe Friend	59.54	—	0.020	—	—	—	—	—	0.72	—	38.60
Negaunee	63.68	4.55	0.057	0.25	2.64	0.75	0.15	0.025	10.67	—	56.75
Negaunee, Non-Bessemer ..	62.30	4.30	0.115	0.30	2.90	0.92	0.20	0.025	10.67	—	55.65
Negaunee, Silica	43.00	36.18	0.36	0.28	0.60	0.62	0.37	trace	0.68	—	42.62
Non-Bess. Old Mine, Hem. ..	62.00	8.00	0.180	0.45	2.75	0.68	0.21	0.020	7.78	—	56.11
Norfolk	55.00	13.75	0.060	0.09	2.60	1.10	1.06	0.080	1.12	—	55.47
Oxford	64.60	4.45	0.075	0.32	1.80	0.25	0.28	0.020	1.14	—	66.76
Peninsula	59.00	9.20	0.118	0.31	1.92	0.82	0.41	0.007	10.80	1.47	52.63
Peninsula, A	54.30	15.20	0.090	0.24	1.95	0.62	0.43	0.010	—	2.20	—
Platt	58.70	—	0.088	—	—	—	—	—	8.78	—	52.55
Prince of Wales	61.55	6.10	0.122	0.36	1.72	1.40	0.46	0.012	10.40	2.20	55.15
Queen	62.40	6.80	0.110	0.22	1.40	0.86	0.72	0.002	10.65	1.64	55.76
Regent	62.30	7.27	0.048	0.23	1.95	0.33	0.09	0.008	10.25	1.27	55.91
Republic, Kingston ..	64.73	5.28	0.036	0.09	1.30	0.86	0.16	0.080	1.31	—	63.88
Republic, Special	67.38	—	0.021	—	—	—	—	—	1.02	—	66.70
Republic, Specular ..	67.62	2.35	0.034	trace	0.69	0.30	0.09	0.018	1.31	—	66.73
Salisbury	62.10	4.91	0.113	0.30	1.42	0.36	0.19	0.017	12.12	—	54.66
Salisbury, Bessemer ..	63.04	5.80	0.049	0.21	1.23	0.21	0.40	0.022	11.93	—	55.62
Salisbury, Silica	49.31	24.10	0.054	0.36	2.20	0.35	0.18	0.016	11.10	—	43.88
Savoy	62.05	7.75	0.075	0.34	1.85	0.27	0.17	0.025	1.82	—	60.87
Sawmill	60.00	—	0.060	—	—	—	—	—	0.84	—	—
Section 16, No. 1 Bessemer ..	65.39	3.13	0.014	0.23	1.65	0.24	0.17	0.015	3.99	—	62.78
Section 16, No. 2 Bessemer ..	61.66	7.75	0.032	0.23	1.70	0.17	0.19	0.015	2.14	—	60.34
Section 16, Now Shaft ..	63.48	5.43	0.030	0.27	1.49	0.27	0.18	0.016	2.04	—	62.16
Sheffield	62.08	—	0.018	—	—	—	—	—	3.50	—	59.91
South Buffalo	61.95	5.70	0.115	0.39	1.75	0.92	0.71	0.005	10.90	1.70	55.20
Swansey	62.30	5.96	0.077	0.38	1.39	0.76	0.42	0.045	18.00	—	—
Volunteer	57.79	12.46	0.069	0.20	2.28	0.29	1.73	0.019	1.50	—	56.94
Winthrop	61.25	6.88	0.140	0.71	1.34	0.44	0.38	0.027	11.37	—	54.29

* Ores dried at 212° Fahr. before analysis.

APPENDIX B.—Continued.

MENOMINEE RANGE.

Trade Name of Grade.	Iron.	Silica.	Phosphorus.	Manganese.	Aluminum.	Lime.	Magnesium.	Sulphur.	Moisture.	Volatile Matter.	Natural.
Appleton	63.30	4.81	0.018	0.27	1.30	0.63	0.47	0.019	8.60	—	57.93
Aragon	63.80	3.25	0.080	0.10	0.98	0.20	0.11	0.011	6.78	—	58.32
Badger	59.20	4.83	0.131	0.42	2.76	1.10	2.89	0.110	9.07	—	53.67
Chapin	60.91	3.16	0.063	0.39	1.16	1.07	3.79	0.013	6.72	—	56.62
Chapin, Rex	57.68	5.65	0.063	0.81	1.21	1.48	4.39	0.016	6.53	—	53.91
Claire	54.46	3.65	1.21	1.96	1.13	3.20	1.22	0.015	6.60	—	50.92
Clifford	41.87	37.80	0.011	0.10	1.00	0.35	0.34	0.012	2.14	—	40.97
Crystal Falls	58.55	4.25	0.731	0.20	1.16	2.64	0.77	0.008	7.20	2.92	51.30
Davidson	56.06	6.23	0.170	0.37	3.41	1.54	3.97	0.101	8.40	—	51.33
Dunn	58.61	3.88	0.573	0.58	1.88	1.80	0.88	0.033	8.70	—	52.51
Elmwood	58.10	5.91	0.173	0.42	3.06	1.03	2.38	0.096	9.05	—	52.67
Florence	57.60	4.67	0.343	trace	2.65	1.20	1.53	0.214	7.59	—	53.23
Grenada	63.78	4.30	0.092	0.23	1.34	0.35	1.06	0.003	6.70	—	59.51
Great Western	61.03	3.98	0.249	0.92	2.31	0.92	1.66	0.082	6.50	—	57.03
Hemlock	60.20	4.71	0.309	0.39	2.81	1.87	1.32	0.010	6.62	—	56.24
Hiawatha	61.60	3.65	0.13	0.27	1.86	0.93	0.27	0.082	6.00	—	57.90
Iron River	59.80	5.29	0.356	0.37	3.41	0.69	0.37	0.028	9.50	—	54.11
Keel Ridge	40.64	37.42	0.046	0.20	0.90	1.35	1.00	0.006	2.90	—	39.46
Lincoln	60.86	3.86	0.24	0.45	1.67	2.14	1.73	0.010	6.50	—	56.91
Loretto	60.51	8.82	0.018	0.29	1.92	0.15	0.47	0.077	8.69	—	55.25
Ludington	55.60	—	0.024	—	—	—	—	—	7.06	—	60.97
Ludington Star	63.43	3.25	0.087	0.34	1.05	0.90	1.80	trace	7.50	—	56.67
Mansfield	63.86	4.14	0.044	0.38	1.97	0.46	0.28	0.019	11.00	—	56.39
Mastodon	61.00	4.60	0.350	0.30	2.75	0.60	0.30	0.075	9.00	—	55.51
Millie	62.10	3.20	0.027	0.20	1.25	1.08	1.05	0.030	5.47	—	56.70
Paint River	56.40	3.48	0.502	0.378	4.12	5.58	0.72	0.063	8.00	—	51.99
Pewabic	64.36	3.35	0.009	0.19	0.48	1.10	1.35	0.003	6.46	—	60.16
Pewabic, Genoa	42.79	35.28	0.007	0.10	0.96	0.52	0.95	—	4.32	—	40.94
Pewabic, Homestead	54.87	4.68	0.086	0.38	2.05	3.48	4.87	0.003	—	—	—
Pewabic, Toledo	53.55	18.23	0.010	0.18	0.65	1.20	1.57	0.003	6.28	—	50.18
Pewabic, Tyrone	62.00	3.91	0.106	0.19	0.72	1.50	1.90	0.003	—	—	—
Rex	57.68	5.65	0.063	0.81	1.21	1.48	4.39	0.016	6.53	—	53.93
San Jose	56.41	3.23	0.013	0.24	1.24	0.16	0.25	0.043	7.60	—	60.44
Sheridan	58.50	6.50	0.130	0.50	4.00	0.60	0.70	0.250	9.12	—	53.26

GOCEBIC RANGE.

Trade Name of Grade.	Iron.	Silica.	Phosphorus.	Manganese.	Aluminum.	Lime.	Magnesium.	Sulphur.	Moisture.	Volatile Matter.	Natural.
Anvil	62.74	4.09	0.055	0.82	1.10	0.47	0.11	0.018	12.88	—	55.00
Anvil, East Vein	61.00	5.25	0.058	2.18	0.86	0.08	trace	0.014	12.76	—	53.22
Ashland, Special	63.02	4.32	0.035	0.21	1.92	0.12	0.14	0.021	10.70	—	56.26
Atlantic	62.27	4.59	0.040	1.11	1.15	0.18	0.07	0.023	10.48	—	55.74
Aurora	63.20	4.02	0.028	0.48	1.10	0.37	0.01	0.022	9.68	—	57.08
Brotherton	62.60	7.05	0.037	0.46	1.10	0.30	0.10	0.004	11.11	—	55.65
Cary Empire	58.10	3.65	0.062	4.55	1.25	0.16	0.10	0.015	8.23	—	58.29
Colby	56.80	3.20	0.071	5.75	0.98	0.24	0.18	0.010	9.30	2.10	51.61
Cromwell	60.00	3.75	0.132	3.10	0.73	0.10	0.13	0.010	9.58	—	54.25
Eureka	61.65	6.75	0.065	1.40	0.95	0.52	0.22	0.011	9.80	1.97	55.61
Iron Belt	62.55	5.05	0.042	0.54	1.65	0.10	0.02	0.015	10.67	—	55.68
Lawrence	60.39	8.90	0.056	0.45	1.30	0.09	0.02	0.023	9.72	—	54.52
Melrose	63.07	2.96	0.029	1.08	0.78	0.10	0.08	0.016	9.11	—	57.82
Montreal	64.90	4.10	0.042	0.33	1.02	0.10	0.06	0.025	8.57	—	59.37
Newport	55.70	3.30	0.040	7.40	0.98	0.80	0.07	0.016	9.44	—	50.44
Norrie	63.34	3.62	0.041	0.34	1.74	0.19	0.18	0.017	9.73	—	57.16
Pabst	63.93	—	0.040	—	—	—	—	—	9.19	—	58.07
Palms	63.19	3.62	0.048	0.88	1.11	0.16	0.10	0.018	11.58	—	56.87
Pearce	58.60	11.44	0.062	0.64	0.81	0.22	0.13	0.014	7.60	2.07	54.11
Penoc	65.20	6.60	0.019	0.24	0.28	0.16	0.06	0.014	—	—	—
Rand	59.80	5.25	0.033	3.21	1.07	0.66	0.60	0.017	9.18	—	54.23
Shore, Bessemer	65.23	4.48	0.029	0.29	0.55	—	—	—	7.50	—	60.84
Sunday Lake	62.45	8.50	0.022	0.54	0.77	0.15	0.06	0.010	12.20	0.54	54.21
Tilden	63.60	8.97	0.042	0.78	1.38	0.22	0.21	0.009	12.46	—	55.68
Windsor	64.00	4.00	0.048	0.68	0.80	0.31	0.10	0.008	—	—	—

APPENDIX B.—Continued.

VERMILION RANGE.

Trade Name of Grade.	Iron.	Silica.	Phos- phorus.	Man- ganese.	Alu- minium.	Lime.	Mag- nesium.	Sul- phur.	Mole- ture.	Volatile Matter.	Natural
Chandler	64.70	4.26	0.088	0.18	1.87	0.83	0.10	trace	5.79	—	60.95
Chandler, Long Lake ..	60.59	7.80	0.040	0.18	1.85	0.72	0.20	0.004	7.55	—	55.02
Minnesota	87.74	1.55	0.048	0.00	0.90	0.27	0.12	0.00	2.00	—	66.89
Minnesota, Red Lake ..	64.41	8.74	0.108	0.00	1.81	0.85	0.11	trace	—	—	—
Minnesota, Soudan	65.81	4.86	0.104	0.00	0.68	0.62	0.28	trace	—	—	—
Minnesota, Vermilion ..	87.86	1.68	0.156	0.00	0.62	0.60	0.25	0.00	—	—	—
Pioneer	64.95	4.50	0.085	0.21	1.60	0.16	0.07	0.020	8.11	—	59.68
Zenith	86.02	2.96	0.049	0.14	1.61	0.12	0.07	0.009	5.62	—	62.38

MESABI RANGE.

Adams	64.18	2.80	0.085	0.40	0.80	0.21	0.10	0.007	7.29	3.80	59.51
Anburn	65.04	2.25	0.047	0.89	1.47	0.68	0.15	trace	9.56	—	58.82
Auburn, Andrey	62.69	2.64	0.071	0.66	1.52	0.25	0.14	trace	12.07	—	55.12
Berringer	61.16	4.55	0.065	0.88	1.59	0.11	0.07	0.012	8.91	—	55.71
Biwabik	64.61	8.00	0.033	0.25	0.50	0.24	0.15	0.005	7.71	3.40	59.68
Canton	60.80	4.25	0.048	0.49	0.98	0.71	0.07	trace	9.97	—	54.74
Canton, Climax	68.64	1.94	0.036	0.87	0.60	0.88	trace	trace	8.65	—	57.18
Cincinnati	61.50	6.32	0.037	0.69	0.98	0.34	0.15	0.015	8.00	—	56.58
Cincinnati, Silica	59.00	8.00	0.030	0.60	1.00	0.34	0.15	0.015	8.00	—	54.28
Commodore	68.60	4.10	0.038	0.12	0.90	0.87	0.04	0.011	10.25	3.40	57.08
Fayal	62.55	8.06	0.037	1.00	1.80	0.26	0.14	trace	9.55	—	56.58
Franklin	62.79	4.12	0.036	0.69	0.80	0.80	0.26	0.021	6.26	—	58.86
Genoa	62.70	3.75	0.033	0.65	1.16	0.60	0.19	0.00	11.29	—	55.62
Hale	60.00	5.00	0.100	0.55	0.52	1.58	—	0.016	9.00	—	54.60
Junata	62.40	3.30	0.065	0.67	4.62	0.05	trace	0.013	10.00	—	56.16
Lake Superior, Burt	65.48	8.17	0.034	0.49	1.43	0.56	0.20	0.006	8.97	—	59.61
Lake Superior, Hull	65.52	2.43	0.024	0.19	0.79	0.02	0.14	0.018	10.79	—	58.45
Lake Superior, Rust	65.00	2.50	0.030	0.25	1.25	0.25	0.15	0.012	9.25	—	58.99
Lindwood	68.59	4.25	0.054	0.45	1.55	0.60	0.23	0.010	8.95	—	57.90
Lowmore	64.00	8.50	0.045	0.50	1.85	0.35	0.15	0.010	11.00	—	56.96
Mahoning	64.28	2.75	0.050	0.33	1.50	0.20	0.65	0.020	10.84	—	57.65
Mahoning, Beaver	64.44	2.90	0.080	0.17	1.50	0.20	0.10	0.012	10.61	—	57.69
Mahoning, Shenango	64.07	2.69	0.060	0.30	1.62	0.20	0.16	0.020	10.53	—	57.83
McKinley	62.30	8.36	0.026	0.37	0.93	0.48	0.28	0.016	8.75	—	56.85
Minnewas	65.63	2.25	0.047	0.35	1.12	0.20	0.03	0.008	9.00	—	59.60
Mountain Iron, Helmer ..	64.18	3.65	0.051	0.48	1.80	0.15	0.10	0.015	11.15	—	57.02
Mountain Iron, Tubal ..	68.25	4.50	0.065	0.45	1.75	0.20	0.08	0.018	11.54	—	56.95
Norman	62.15	3.75	0.069	0.90	1.82	0.62	0.13	trace	8.41	—	58.91
Norman, Saxon	64.29	3.75	0.039	0.56	1.21	0.12	0.04	—	8.00	—	59.15
Ohio	61.58	4.60	0.082	0.40	1.45	0.38	0.25	0.007	6.95	—	57.25
Ohio, Katonah	64.41	2.95	0.053	0.40	1.34	0.87	0.25	0.006	8.85	—	59.03
Oliver	63.31	4.53	0.053	0.51	2.10	0.20	0.47	0.010	9.07	—	57.58
Oliver, Preble	60.00	4.75	0.060	1.67	3.58	0.10	0.108	0.020	9.56	—	54.26
Roberts	62.00	7.67	0.030	0.23	0.66	0.15	0.12	0.002	7.00	—	57.66
Sellers	64.23	3.66	0.086	0.38	0.95	0.19	0.12	0.019	8.73	—	58.62
South Side	61.05	4.22	0.070	—	3.40	0.25	0.10	0.018	9.68	—	58.14
Vega	61.99	5.40	0.040	0.26	1.45	0.58	0.18	—	11.67	—	54.82
Vega, Mangan	59.80	5.50	0.034	0.68	1.52	0.82	0.10	—	18.55	—	51.70
Vega, Valley	61.03	5.66	0.041	0.31	—	—	—	—	12.76	—	58.24
Williams	60.40	9.20	0.036	0.77	0.95	0.42	0.12	0.011	9.70	—	54.54

APPENDIX C.—PRE-SILURIAN

MINNESOTA.				SUPPORTED	
				Wisconsin Reports.	
PALÆOZOIC.	CAMBRIAN. ¹		St. Peter sandstone. ¹ Shakopee limestone. Richmond sandstone. Lower Magnesian limestone. St. Croix Series. Hinkley sandstone. (L. Superior sandstone.) Brown sandstones. Fond du Lac.	CAMBRIAN.....	St. Peter. Willow River. New Richmond. Main body of limestone. Madison. Mendota sandstone. L. Superior sandstone. } Potsdam.
				Unconformity.	
	TAONIC. ⁴	Keweenawan.	Upper. Traps and amygdaloids. (Upper series.) Sioux quartzite ⁵ and conglomerate.	KEWEENAWAN	Upper. Horizontal sandstones.
			Lower (Norian)		Lower. Traps, Amygdaloids, Conglomerates.
				Unconformity.	
		Animikie.	Wausauquoning quartzite. Slates, iron-ores, etc., of the Mesabi range. Pewabic quartzite.	Divided into twenty-one parts.	
Great unconformity.					
ARCHÆAN.	ONTARIAN....	Keewatin.	Sericitic schists, green schists, greenstones, slates, graywackes, conglomerates, jaspilite, iron ores, etc., of the Vermilion range.	HURONIAN....	
		Coutchiching ⁶ (Vermilion).	Holocrystalline mica and hornblende schists.		
Eruptive unconformity.					
LAURENTIAN.		Gneiss.			

¹ The St. Peter sandstone has been put in the Cambrian in the reports of the Minnesota Survey already published, but recent developments indicate that it belongs to the Lower Silurian.
² Cambrian is regarded as the time-equivalent of the Upper Cambrian, as that term is used by the U.S. Geological Survey.
³ Some parts of the Cambrian are unconformable on the Lower Keeweenawan, but there is no evidence to show the exact date or the kind of disturbance that brought about this change.

ROCKS OF MINNESOTA.*

EQUIVALENTS.		GENERAL TERMS USED BY THE U. S. GEOLOGICAL SURVEY.		TERMS USED BY THE GEOLOGICAL SURVEY OF CANADA.		
Michigan (Wadsworth).		PALÆOZOIC.	UPPER CAMBRIAN.			
PALÆOZOIC.	Calcliferous.			4. Calcliferous?		
	CAMBRIAN.	Unconformity.		3. Potsdam.		
	Potsdam (Keeweenawan).	ALGONKIAN.	KEEWEEANAWAN.	2. Keeweenawan.		
			Unconformity.	2. and 3. Selkirk Series.		
			UPPER HURONIAN.	1. Animikie, Bow river and Nisconlith Series.		
			Unconformity.	1. St. John Group.		
			Lower Huronian.			
Great unconformity.		Unconformity.		Great and universal unconf.		
AZOIC OR ARCHÆAN.	Negaunee.	ARCHÆAN OR BASEMENT COMPLEX. }	MARENISCAN. ----- Eruptive unconf. ----- LAURENTIAN.			
	MICHIGAN.....					
	Holyoke.					
	Unconformity.					
	Mesnard.					
	HURONIAN?....	ARCHÆAN	LAURENTIAN.	HURONIAN.		
	Unconformity.					
	Republic.					
	Unconformity.	Unconformity.		Local unconformities.		
	LAURENTIAN?..					
	Cascade.					

* The two divisions of the Taconic, Keeweenawan and Animikie, are regarded as the time-equivalents of the Middle and Lower Cambrian, respectively, as these terms are used by the U.S. Geological Survey.

* In the Minnesota reports, this has been considered the true Potsdam.

* The term Cutchiebung antedates Vermilion, but in the Minnesota reports already published the latter has been used instead of the former.

* With a few modifications from the original table.

APPENDIX D.—LAKE SUPERIOR IRON ORE SHIPMENTS (GROSS TONS) FOR 1896 AND THE PAST FORTY-ONE YEARS.*

Name of Mine.	Prior to 1885.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	TOTALS.
MARQUETTE RANOM.														
American (Sterling) ..	Tons. 20,089	Tons. —	Tons. —	Tons. 1,488	Tons. 18,699	Tons. 20,082	Tons. 21,000	Tons. 21,604	Tons. 18,076	Tons. 1,108	Tons. 6,198	Tons. —	Tons. —	Tons. 112,983
Ames ..	—	—	—	—	—	—	—	—	—	—	—	—	—	6,298
Barnum (B) ..	662,249	47,458	52,975	16,128	10,211	12,868	—	—	—	—	—	—	—	801,861
Bay State ..	16,687	—	—	—	—	—	—	—	—	—	—	—	—	16,687
Beasle ..	—	—	—	—	—	—	—	847	—	—	—	—	—	847
Beauford ..	42,868	17,166	17,354	12,829	—	—	—	—	—	—	—	—	—	90,217
Blus ..	61,955	—	—	—	—	—	—	—	—	—	—	—	—	90,120
Buffalo (A) ..	—	—	10,860	24,866	80,801	80,919	100,464	—	—	18,809	82,171	44,140	887	82,542
Brasatad { Mitchell ..	109,109	—	7,017	16,419	4,091	—	—	—	—	—	—	—	—	217,780
Champion ..	402,592	83,913	58,743	74,067	86,789	155,841	—	—	—	—	—	—	—	136,698
Cambria ..	227,499	80,796	58,784	41,180	57,861	72,780	80,859	84,662	41,649	80,445	47,218	41,656	96,086	831,445
Champion ..	1,450,056	173,915	137,693	146,830	174,680	216,098	228,442	188,418	109,979	61,648	42,788	100,398	118,876	879,825
Chester (Swansey) ..	148,526	—	8,328	2,842	—	—	—	7,801	29,403	19,098	—	6,898	—	217,069
Chicago ..	9,012	—	—	—	—	—	—	—	—	—	—	—	—	9,012
Cleveland Iron Co. ..	8,075,092	218,757	203,664	207,441	184,316	274,048	331,718	321,788	310,907	218,105	148,708	221,163	518,119	6,123,809
Columbia (Klomen) ..	94,813	—	—	—	—	16,671	—	—	—	—	—	—	—	94,813
Curry ..	—	—	—	—	—	—	—	—	—	—	—	—	—	16,671
Detroit ..	21,628	19,125	39,400	26,099	18,500	10,112	6,080	—	—	—	—	—	—	140,841
Dexter ..	21,080	750	—	—	1,821	8,896	9,186	5,448	18,000	7,838	21,740	13,762	18,908	117,863
Dey ..	2,709	—	—	—	—	—	—	—	—	—	—	—	—	2,709
East Champion ..	72,205	—	—	—	—	2,697	—	—	—	—	—	—	—	75,008
East New York ..	—	—	—	—	—	28,739	86,481	50,298	85,175	911	—	—	—	166,243
Edison ..	—	—	—	—	—	898	—	—	—	—	—	—	—	898
Erie ..	8,136	—	—	—	—	—	—	—	—	—	—	—	—	8,136
Etna ..	1,091	—	—	—	—	—	—	—	—	—	—	—	—	1,091
Fitch ..	—	—	—	—	—	—	10,350	15,098	—	—	—	174	—	17,193
Foster (B) ..	140,801	9,643	—	—	—	—	21,949	—	—	—	—	—	—	171,893
Gibson ..	48,754	1,515	12,142	2,700	—	—	—	—	—	—	—	—	—	17,487
Goodrich ..	—	—	—	—	—	—	—	—	—	—	—	—	—	48,754
Grand Rapids (Davis) ..	—	—	—	1,200	11,611	20,038	26,426	9,862	22,928	832	12,078	6,764	67	110,786
Hartford ..	—	—	—	—	—	566	—	—	5,678	—	—	—	—	14,289
Hertens (North Champion) ..	—	—	—	846	5,688	7,737	15,246	—	—	—	—	—	1,882	80,874
Humboldt ..	594,588	11,766	20,207	19,873	11,553	23,939	23,939	19,878	4,871	—	—	—	—	80,874
Iron Cliffs (K) ..	—	—	—	87,846	78,920	184,616	188,776	278,270	299,895	180,812	268,760	269,042	2,397	723,961
Imperial ..	—	—	—	—	—	38,460	—	18,862	7,194	—	—	—	—	1,700,587
Iron Mountain ..	—	—	—	—	—	—	—	—	—	—	—	—	—	64,268
Jackson ..	2,445,521	68,657	89,370	109,996	101,909	198,981	124,692	92,979	92,667	61,009	83,294	42,186	—	80,710
Lake Superior ..	3,396,560	286,040	267,829	892,009	246,223	316,824	316,824	808,481	866,715	828,510	844,788	842,439	489,576	7,194,390
Lille ..	116,844	708	2,957	23,041	25,092	38,916	81,812	19,651	29,005	68,961	78,888	54,369	107,882	600,592

A—Now Queen Iron Manufacturing Co.

B—Now Iron Cliffs.

K—Under Cleveland Iron Cliffs Co. after 1895.

* Iron Trade Review, Cleveland, Ohio, 1897, vol. xxx., No. 3.

APPENDIX D.—LAKE SUPERIOR IRON ORE SHIPMENTS.—Continued.

Name of Mine.	Prior to 1888.	1888.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	TOTALS.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Lucy (McComber) ..	807,437	—	13,139	—	82,962	43,483	27,688	—	26,226	21,964	—	—	—	494,290
Xiangou ..	1,861	8,111	—	1,827	—	—	—	—	—	—	—	—	—	6,859
Marquette (C) ..	—	—	20,441	6,329	70,128	23,692	16,802	—	9,555	—	—	—	—	192,907
Meabi's Friend ..	—	—	—	—	—	—	—	—	—	—	—	5,608	—	16,043
Michigan ..	565,437	12,373	58,726	48,790	86,989	80,777	23,169	—	1,694	985	1,610	—	—	890,382
Milwaukee ..	113,406	38,466	60,490	46,693	82,727	24,763	—	—	—	—	—	—	—	875,481
National ..	180,316	—	—	—	—	—	—	—	—	—	—	—	—	160,216
Negaunee ..	—	—	5,289	6,285	45,804	76,318	64,218	—	86,546	69,782	182,681	90,683	176,894	828,822
Construction Works ..	11,614	—	—	1,094	—	—	—	—	—	—	—	—	—	12,706
New York (York) ..	1,038,001	—	5,128	—	12,844	2,422	—	—	11,220	26,000	21,487	—	—	1,118,102
New York Hematite ..	87,687	—	—	—	—	—	—	—	—	—	—	—	—	87,687
North Republic ..	—	—	—	—	—	—	—	—	—	—	—	—	—	289
Northwest ..	—	—	2,200	—	—	—	—	—	1,687	—	—	—	—	1,687
Norwood ..	—	—	1,486	—	—	—	—	—	—	—	—	—	—	6,783
Nonpareil (St. Lawrence) ..	21,959	—	—	—	—	—	—	—	—	—	—	—	—	23,896
Palmer ..	—	18,249	—	—	—	—	—	—	—	—	—	—	—	1,041
Pascoe ..	31,486	—	—	10,072	—	—	—	—	—	—	—	—	—	93,806
Pendill ..	48,983	—	—	—	—	—	—	—	—	—	—	—	—	45,993
Phenix (Dallies) ..	87,509	—	—	—	—	—	—	—	—	—	—	—	—	88,114
Pioneer ..	—	—	1,605	—	—	—	—	—	—	—	—	—	—	15,409
Pitta. and L. Argeline ..	—	—	1,203	5,140	2,068	—	—	—	287,517	351,978	355,453	818,656	842,221	8,694,811
Platt ..	664,204	111,081	191,120	131,731	223,600	229,070	261,681	241,605	2,676	5,448	41,228	16,198	11,296	78,844
Primrose ..	—	—	—	—	—	—	—	—	—	—	—	—	—	6,040
Prince of Wales (A) ..	—	—	—	—	—	—	—	—	—	—	—	—	—	82,415
Quarta ..	—	—	—	—	491	—	—	—	—	—	—	—	—	491
Queen (A) ..	—	—	—	—	66,123	—	—	—	—	—	—	—	—	180,866
Queen Iron Manufg. Co. (P) ..	—	—	—	—	5,527	109,217	479,509	379,719	106,864	320,298	180,817	323,057	1,670,264	1,670,264
Republic ..	2,092,830	241,161	220,434	287,390	220,065	191,127	167,991	64,196	—	—	108,719	174,027	127,860	4,878,886
Republic Reduction Co. ..	—	—	—	—	22,122	8,915	—	—	—	—	—	—	—	47,174
Richards ..	—	—	1,874	—	—	—	—	—	—	—	—	—	—	1,874
Richmond ..	—	—	—	—	—	—	—	—	—	—	—	—	—	1,088
Riverdale ..	—	—	—	—	5,622	8,712	—	6,733	—	—	—	—	—	15,180
Rolling Mill ..	238,325	3,437	1,058	4,403	402	—	—	—	—	48	—	—	—	284,628
Saginaw ..	447,104	—	—	—	—	—	—	4,320	—	—	—	—	—	451,424
Salisbury (B) ..	323,743	29,503	81,867	48,804	73,449	85,798	—	—	—	—	—	—	—	698,411
Sam Mitchell ..	—	—	8,923	8,411	546	—	—	—	—	—	—	—	—	17,790
Sauson (Argyle) ..	287,646	—	—	1,133	2,796	1,218	—	—	600	—	—	—	—	287,808
Schadt ..	—	—	—	—	—	—	—	—	—	—	—	—	—	11,381
Section 12 ..	—	—	—	—	—	—	—	—	—	—	—	1,261	—	11,381
South Buffalo (A) ..	21,867	—	4,964	—	24,706	69,859	146,383	—	—	—	—	—	—	21,867
	—	—	—	—	—	—	—	—	—	—	—	—	—	245,412

A—Now Queen Iron Manufacturing Co. B—Now Iron Cliffs. C—Later in Winthrop. F—Succeeds Buffalo Mining Co.

APPENDIX D.—LAKE SUPERIOR IRON ORE SHIPMENTS—Continued.

Name of Mine.	Prior to 1885.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	TOTALS.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Spurr ..	163,492	753	17,588	4,987	15,141	4,412	—	—	—	—	5,550	—	—	164,944
Star West (Whale)	39,447	9,900	15,867	—	—	—	—	—	—	—	—	51,207	9,658	181,004
Taylor ..	32,970	—	—	—	—	—	—	—	—	—	—	—	—	32,970
Thames ..	34,317	23,840	18,868	16,008	141,524	92,698	—	—	—	—	—	—	—	90,871
Volunteer ..	335,747	5,679	24,084	47,486	60,156	60,448	—	—	127,180	69,561	26,946	82,672	53,216	1,073,171
Wabigoon ..	5,377	6,399	2,084	9,861	1,510	—	—	—	—	—	—	—	—	14,106
West Republic ..	85,576	12,700	10,518	12,873	1,510	—	—	—	—	—	—	—	—	135,077
Wescott ..	9,139	4,987	10,746	2,355	2,074	—	—	—	—	—	—	—	—	50,870
Winchell ..	4,098	6,583	—	—	—	—	—	—	—	—	—	—	—	10,686
Winthrop ..	—	—	—	—	—	—	109,576	122,042	191,686	160,071	184,865	119,120	150,496	1,007,828
Totals ..	20,392,167	1,480,432	1,637,890	1,961,684	1,928,727	2,642,813	2,998,664	2,612,242	2,666,866	1,888,898	2,039,880	2,097,888	2,604,221	46,589,187
MESABI RANGE.														
Adams ..	—	—	—	—	—	—	—	—	—	—	—	59,141	234,562	293,703
Adna (Lowmore)	—	—	—	—	—	—	—	—	—	—	—	—	17,728	19,868
Auburn ..	—	—	—	—	—	—	—	—	—	—	—	876,970	181,478	616,658
Bitwabik ..	—	—	—	—	—	—	—	—	—	—	—	247,069	242,566	781,182
Canton ..	—	—	—	—	—	—	—	—	—	—	—	889,020	16,281	618,550
Chickadee ..	—	—	—	—	—	—	—	—	—	—	—	17,187	57,824	100,888
Cloquet (Vega)	—	—	—	—	—	—	—	—	—	—	—	47,700	96,290	149,608
Commodore ..	—	—	—	—	—	—	—	—	—	—	—	—	22,068	94,418
Duluth ..	—	—	—	—	—	—	—	—	—	—	—	—	—	87,626
Fayal ..	—	—	—	—	—	—	—	—	—	—	—	186,601	248,645	885,246
Franklin ..	—	—	—	—	—	—	—	—	—	—	—	286,428	231,086	787,525
Genoa ..	—	—	—	—	—	—	—	—	—	—	—	81,004	70,008	128,788
Hale ..	—	—	—	—	—	—	—	—	—	—	—	68,128	87,659	128,782
Lake Superior ..	—	—	—	—	—	—	—	—	—	—	—	117,884	167,246	285,129
Mahoning ..	—	—	—	—	—	—	—	—	—	—	—	—	—	15,998
Mountain Iron (and Rath.)	—	—	—	—	—	—	—	—	—	—	—	871,374	142,021	1,210,788
Norman ..	—	—	—	—	—	—	—	—	—	—	—	98,892	77,628	309,914
Ohio ..	—	—	—	—	—	—	—	—	—	—	—	28,945	69,928	98,868
Oliver (I)	—	—	—	—	—	—	—	—	—	—	—	600,877	808,291	1,987,688
Sellers ..	—	—	—	—	—	—	—	—	—	—	—	47,483	168,087	300,470
Williams (North Chickadee)	—	—	—	—	—	—	—	—	—	—	—	8,046	11,249	14,296
Totals ..	—	—	—	—	—	—	—	—	4,245	618,690	1,798,082	2,781,887	2,989,079	8,074,688
Miscellaneous ..	1,879	441	—	—	—	—	—	—	—	—	—	—	—	2,820

I - Mesabi Mountain and Lone Jack.

APPENDIX D.—LAKE SUPERIOR IRON ORE SHIPMENTS.—Continued.

Name of Mine.	Prior to 1885.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	TOTALS.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
MCKINNEY RANGE.														
Antone ..	—	—	—	—	—	—	—	—	—	—	—	—	—	188,743
Appelon ..	—	—	—	—	—	—	—	—	—	—	—	—	—	13,109
Aragon ..	—	—	—	—	—	1,746	46,609	96,939	4,377	5,418	—	97,931	110,821	869,846
Ardena ..	—	—	—	—	—	60,276	26,649	—	167,948	197,901	185,209	183,298	96,809	78,989
Beta ..	—	—	1,565	1,228	—	—	—	1,400	—	—	—	—	—	4,811
Breen ..	—	—	—	—	—	—	—	—	—	—	—	—	—	17,480
Brier Hill ..	—	—	—	—	—	—	—	—	—	—	—	—	—	14,981
Calumet ..	—	—	—	—	—	—	—	—	—	—	—	—	—	89,713
Chapin ..	—	—	—	—	—	—	—	—	—	—	—	—	—	6,131,580
Clare ..	—	—	—	—	—	—	—	—	—	—	—	—	—	68,964
Columbia (H) ..	—	—	—	—	—	—	—	—	—	—	—	—	—	446,418
Commonwealth ..	—	—	—	—	—	—	—	—	—	—	—	—	—	59,707
Cornell ..	—	—	—	—	—	—	—	—	—	—	—	—	—	43,802
Crysal Falls ..	—	—	—	—	—	—	—	—	—	—	—	—	—	82,678
Cundy (Quinnesec) ..	—	—	—	—	—	—	—	—	—	—	—	—	—	287,479
Curry (G) ..	—	—	—	—	—	—	—	—	—	—	—	—	—	3,396
Cyclops (G) ..	—	—	—	—	—	—	—	—	—	—	—	—	—	761
Delphic ..	—	—	—	—	—	—	—	—	—	—	—	—	—	288,098
Dunn ..	—	—	—	—	—	—	—	—	—	—	—	—	—	83,770
Emmett ..	—	—	—	—	—	—	—	—	—	—	—	—	—	969,046
Fairbank ..	—	—	—	—	—	—	—	—	—	—	—	—	—	66,666
Florence ..	—	—	—	—	—	—	—	—	—	—	—	—	—	8,500
Great Western ..	—	—	—	—	—	—	—	—	—	—	—	—	—	36,126
Groveland ..	—	—	—	—	—	—	—	—	—	—	—	—	—	1,127,483
Half and Half ..	—	—	—	—	—	—	—	—	—	—	—	—	—	14,643
Hamilton ..	—	—	—	—	—	—	—	—	—	—	—	—	—	1,049
Hemlock ..	—	—	—	—	—	—	—	—	—	—	—	—	—	7,534
Hesper ..	—	—	—	—	—	—	—	—	—	—	—	—	—	96,073
Hawatha ..	—	—	—	—	—	—	—	—	—	—	—	—	—	207,907
Hollerter ..	—	—	—	—	—	—	—	—	—	—	—	—	—	965
Hope ..	—	—	—	—	—	—	—	—	—	—	—	—	—	2,884
Indiana ..	—	—	—	—	—	—	—	—	—	—	—	—	—	4,098
Iron River ..	—	—	—	—	—	—	—	—	—	—	—	—	—	17,813
Keel Ridge ..	—	—	—	—	—	—	—	—	—	—	—	—	—	17,871
Lee Peak (D) ..	—	—	—	—	—	—	—	—	—	—	—	—	—	904,587
Lincoln ..	—	—	—	—	—	—	—	—	—	—	—	—	—	86,201
Loreto ..	—	—	—	—	—	—	—	—	—	—	—	—	—	2,644
Ludington ..	—	—	—	—	—	—	—	—	—	—	—	—	—	86,589
Manganese ..	—	—	—	—	—	—	—	—	—	—	—	—	—	181,608
Mandfield ..	—	—	—	—	—	—	—	—	—	—	—	—	—	1,001,518
	—	—	—	—	—	—	—	—	—	—	—	—	—	6,844
	—	—	—	—	—	—	—	—	—	—	—	—	—	206,946

H—Formerly Smelter, Sheldon, and Union.

G—1883 and later under Penn Iron Mining Co.

D—Cherry Valley Ore.

APPENDIX D.—LAKE SUPERIOR IRON ORE SHIPMENTS.—Continued.

Name of Mine.	Prior to 1885.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	TOTALS.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Mastodon ..	40,241	11,787	41,640	48,793	51,463	68,511	66,526	45,970	9,160	23,486	—	29,783	80	435,708
Metropolitan ..	88,074	—	6,898	9,070	3,490	—	—	—	—	—	—	—	—	107,037
Michigan Exploration Co. ..	—	—	—	—	—	—	—	—	—	—	—	—	—	1,683
Millie (Hewitt) ..	—	4,637	5,517	1,168	11,134	12,274	89,232	5,889	6,790	—	77	1,071	21,815	161,703
Monitor (Lamont) ..	—	—	—	—	—	12,848	31,189	26,328	42,819	13,777	2,600	10,924	—	138,909
Nansaino ..	69,321	—	5,400	90,460	5,744	8,441	—	18,200	—	—	—	—	—	137,666
Northwestern ..	17,906	—	—	—	—	—	—	—	—	—	—	—	—	17,906
Norway (G) ..	768,130	67,741	98,878	98,786	87,360	68,044	61,717	4,089	44,767	—	—	—	—	1,291,382
Paint River ..	24,140	2,878	13,988	10,240	12,606	32,700	62,664	45,438	18,390	280,480	175,374	390,832	179,917	936,983
Penn Iron Mining Co. ..	—	—	—	—	—	—	—	—	—	—	—	—	—	222,871
Perkins ..	211,849	18,020	13,848	10,884	16,684	12,844	11,971	—	—	—	—	—	—	397,225
Perry ..	3,138	—	—	—	—	—	—	—	—	—	—	—	—	3,138
Pewabic ..	—	—	—	—	—	—	26,991	64,507	115,378	168,745	304,010	362,551	273,587	1,212,684
Selden ..	—	—	—	1,802	—	—	—	—	—	—	—	—	—	2,082
Sheridan ..	—	—	—	—	—	1,102	596	7,137	45,748	2,384	—	16,764	3,419	76,986
South Mastodon ..	34,743	—	1,018	8,589	2,722	4,006	1,476	—	—	—	—	—	—	8,208
Stephenson ..	—	—	—	6,839	7,800	4,775	—	—	—	—	—	—	—	89,520
Sturgeon River ..	—	—	148,980	208,086	129,541	188,900	104,998	78,987	179,904	—	—	—	—	78,404
Vulcan (G) ..	648,255	124,125	—	208,086	129,541	188,900	2,440	8,995	—	—	—	—	—	1,668,654
Wajole ..	—	—	26,638	1,740	800	9,614	4,460	3,705	—	—	—	—	—	19,089
Youngstown ..	39,884	—	—	84,418	12,699	—	—	—	—	—	—	—	—	160,764
Totals ..	4,786,028	690,435	880,006	1,198,848	1,191,101	1,796,764	2,382,287	1,824,619	2,381,499	1,466,197	1,187,949	1,623,798	1,860,467	32,994,428
VERMILION RANGE.														
Chandler ..	—	—	—	—	54,612	806,250	336,025	573,969	681,655	488,930	568,040	605,024	471,546	3,798,007
Minnesota ..	62,124	325,464	804,896	894,253	457,841	535,818	682,000	517,870	498,333	870,303	390,463	482,760	448,707	5,109,071
Pioneer ..	—	—	—	—	—	8,144	—	8,079	2,651	—	—	40,064	149,072	310,013
Zenith ..	—	—	—	—	—	—	—	—	14,991	14,388	—	—	18,765	46,144
Totals ..	62,124	325,464	804,896	894,253	511,968	844,692	880,014	894,618	1,167,650	830,621	948,518	1,077,838	1,089,090	9,320,285
GOEBRIC RANGE.														
Anvil ..	—	—	—	10,076	24,676	47,000	45,690	78	42,090	—	13,297	68,064	67,482	308,448
Ashland ..	—	—	—	176,668	174,163	267,915	485,949	287,432	231,866	66,067	82,020	136,096	91,149	1,000,083
Atlantic ..	—	6,741	74,015	1,989	—	—	—	—	—	—	—	70,889	60,737	182,085
Aurora ..	—	6,422	94,848	165,322	179,387	199,865	246,695	83,664	319,493	179,028	203,162	246,883	187,169	2,108,967
Bessemer ..	—	—	—	16,101	—	—	—	—	—	—	—	—	—	20,889
Blue Jacket ..	—	—	—	1,799	—	—	—	—	—	—	—	—	—	1,799
Brotherton ..	—	—	—	58,267	40,689	58,267	80,496	46,574	180,833	18,908	47,148	40,857	50,490	539,510
Cary ..	—	—	—	21,731	—	56,542	118,208	121,186	106,484	26,578	16,659	52,349	38,621	236,729

(1) — 1893 and later under Penn Iron Mining Co.

THE LAKE SUPERIOR IRON-ORE REGION.

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APPENDIX D.—LAKE SUPERIOR IRON ORE SHIPMENTS.—Continued.

Name of Mine.	Prior to 1885.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	TOTALS.
Chicago..	—	84,302	957,482	288,518	285,880	136,833	194,038	9,619	69,988	59,346	32,610	—	504	504
Cobly (E) ..	1,022	—	—	—	2,882	—	2,882	10,144	54,779	9,604	11,782	—	48,493	1,437,966
Comet ..	—	—	—	—	—	—	1,497	—	21,754	15,210	—	10,353	—	89,191
Davis ..	—	—	—	—	—	—	23,734	13,907	10,655	31,385	—	26,103	—	48,714
Eureka ..	—	—	—	—	—	—	63,903	18,769	—	—	—	—	—	128,719
Father Hennepin	—	—	—	—	28,721	76,545	21,150	6,778	—	—	—	—	—	184,928
Federal ..	—	—	—	—	—	—	—	—	—	—	—	—	—	27,928
First National..	—	5,468	19,734	1,997	53,918	103,169	52,000	22,383	4,293	7,364	—	—	—	1,997
Germania ..	—	—	—	61,714	—	—	—	—	8,516	—	—	—	—	830,683
Imperial ..	—	—	—	—	30,000	51,551	110,366	1,506	161,635	23,976	45,109	148,228	81,351	833,724
Iron Belt ..	—	—	—	—	—	—	—	—	—	—	—	—	—	12,199
Iron Chief ..	—	—	—	2,249	—	—	—	300	3,944	—	—	—	—	58,568
Iron Chief No. 2	—	—	—	24,762	—	—	6,247	—	—	1,651	—	—	—	6,395
Ironton ..	—	—	—	—	—	—	—	—	—	—	—	—	—	71,904
Jack Pot ..	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Kakagon ..	—	—	—	52,179	1,228	—	—	—	—	—	—	—	—	4,788
Mikado ..	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Montreal ..	—	23,013	43,988	—	38,015	42,724	16,728	70,108	58,728	34,299	46,037	138,882	131,531	644,084
Newport ..	—	20,184	75,660	—	69,143	30,987	71,488	106,606	168,962	109,718	180,892	167,821	142,369	1,105,332
Nimikon ..	—	4,105	29,217	—	1,813	—	—	—	—	—	—	—	—	28,685
Norrie ..	—	15,419	237,254	—	412,156	674,384	306,728	735,575	985,216	472,062	621,608	738,480	329,068	6,275,841
Odanah ..	—	18,714	30,475	—	13,354	—	—	—	6,711	3,866	2,437	—	—	77,124
Pabst ..	—	1,103	17,879	19,066	49,976	118,376	172,060	139,326	113,245	101,510	406,074	215,960	65,984	1,250,399
Palms ..	—	—	—	1,414	9,725	95,245	50,604	35,227	102,382	2,658	—	46,965	114,108	438,239
Pence ..	—	—	—	—	26,687	574	—	—	—	—	—	—	13,188	40,446
Ruby (Portlan)	—	16,388	45,000	—	8,098	9,472	11,684	918	—	—	—	—	—	86,525
Section 33 ..	—	—	—	—	—	73,870	126,363	38,576	14,681	—	—	—	—	263,590
Shores ..	—	—	—	—	—	—	—	—	—	—	—	—	12,196	12,196
Sparta ..	—	—	—	—	—	—	—	—	2,912	—	—	1,960	—	4,862
Sunday Lake ..	—	1,405	10,963	18,137	—	—	6,010	64,302	56,046	22,876	34,323	20,970	89,441	325,078
Superior ..	—	—	2,690	27,763	—	—	36,675	10,710	13,192	—	—	—	—	121,627
Tilden ..	—	—	—	—	—	—	—	28,415	233,356	185,118	209,077	418,188	260,265	1,274,359
Trumble ..	—	—	10,780	12,764	2,387	—	—	—	—	—	—	—	—	25,931
Tyler's Forks	—	—	—	—	—	—	10,083	—	—	—	—	—	—	10,083
Valley ..	—	—	—	—	—	—	—	—	—	—	—	—	—	1,878
Whidoe ..	—	—	1,878	—	—	14,576	37,210	97	53,242	2,474	—	11,438	28,164	147,181
Totals ..	1,022	119,860	753,862	1,325,878	1,487,096	2,008,394	2,847,310	1,839,574	2,971,991	1,329,355	1,869,468	2,547,976	1,793,971	20,788,787
GRAND TOTALS ..	26,143,218	2,406,042	8,565,144	4,762,107	6,063,877	7,292,643	9,008,725	7,071,033	9,072,241	6,085,716	7,748,312	10,459,037	9,984,828	107,618,540

E—Includes Tilden up to 1891.

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The PRESIDENT moved a vote of thanks to Mr. H. V. Winchell for his interesting paper, and the motion was cordially approved.

Mr. A. L. STEAVENSON read the following paper "On some Dangers Attending the Use of Steam-pipes":—

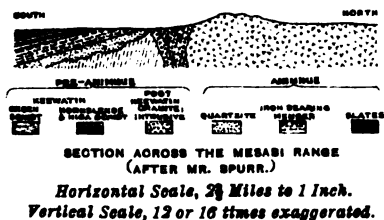


Fig. 8.

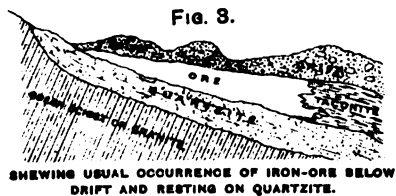


Fig. 4.

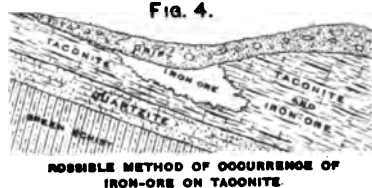


Fig. 5.

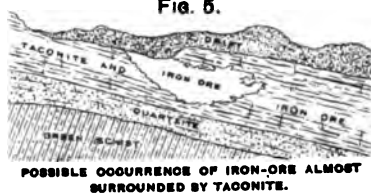


Fig. 6.

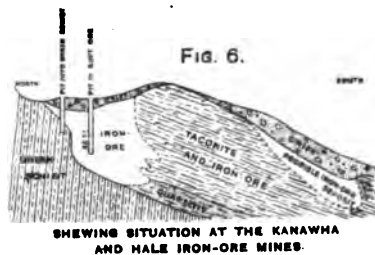
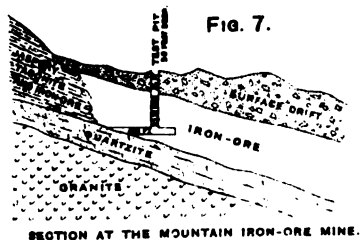


Fig. 7.



ON SOME DANGERS ATTENDING THE USE OF STEAM-PIPES.

By A. L. STEAVENSON.

The writer having learnt from the Secretary that there was likely to be room at this meeting for a short paper, and this subject being one which had been brought under his notice for some time, by a rather curious accident, he has thought it well to put his ideas on the subject into writing.

It will no doubt be within the knowledge of all members who have steam engines, that in 1890 an Act of Parliament was passed which brought all boiler explosions at mines and collieries within the Board of Trade Boiler Explosions Act of 1882, and that since that time it has been decided by the Court of Appeal, that a pipe used for conveying steam was virtually a boiler within the meaning of the Act. The language of the Lord Chancellor was:—"The Act was intended to apply to any instrument or vessel into which steam was admitted for any of those purposes, and of which an explosion might take place, and he saw no reason to restrict the operation of the enactment so as to exclude the present case." That was the steam-pipe of a boiler employed under the Coal-mines Regulation Act.

It therefore becomes necessary whenever a steam-pipe bursts from any cause to send notice within 24 hours to the Board of Trade, giving them all necessary particulars required by the schedule of that Act.

Thickness of Steam-pipes.—It seems somewhat remarkable that in the immense quantity of literature devoted to boilers, the writer has been unable to find the subject of steam-pipes dealt with at all, and even their strength and thickness receive no notice amongst the formulæ given in any of the books on engineering that the writer has been able to consult—with one exception, a book costing a shilling.

Under these circumstances he addressed a letter to the Board of Trade, asking them to tell him how they were guided when any question arose as to the strength of a defaulting steam-pipe. His letter was acknowledged, and his attention directed to their "Rules and Suggestions" as to the survey of steam-ships.

These he procured, but found that nothing was said on the subject. Formulæ for the thickness of copper and wrought-iron pipes are given, but of cast-iron pipes, of which we have such large quantities at mines and collieries, not a word is said.

Now, as many of the members have steam-pipes of 16 or more inches in diameter in daily working, we seem to be in something like a fool's paradise, and attention should be at once given to the matter.

No doubt many of the authorities who have written on engines and boilers have considered the question to be governed by the rules for water-pipes, but the expansion and contraction incidental to the heat which they have to bear seems to necessitate exceptional treatment. Thus, in the only case of a split steam-pipe within the writer's recollection (and which he reported to the Board of Trade) the accident was caused by the boiler-water having been allowed to prime into it, producing sudden contraction; and if, as seems probable, we are working under the ancient and venerable rule of thumb, the sooner we obtain some reliable scientific guidance to support us whenever we have to depend upon ourselves the better.

The following is an extract from the Board of Trade report on an explosion of a steam-pipe at Tursdale colliery on June 5th, 1895:—

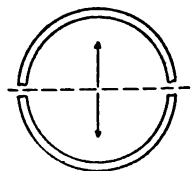
The exploded pipes were broken up after the explosion. In one case, the core had been $\frac{1}{4}$ inch eccentric when casting, the pipe being 1 inch thick on the top side and $\frac{1}{4}$ inch on the bottom, but the material appeared to be sound and of good quality. . . .

The pipe was of cast-iron, and the failure is attributed to the unequal expansion of the metal produced by the partial cooling. Stresses, produced in this way, are frequently much in excess of those produced by the steam-pressure, and cast-iron is not a material that is well suited to sustain such stresses, and the cause assigned for the explosion is probably correct, especially having regard to the nature of the fracture. Fortunately no one was injured by the explosion.*

Of course it may be said that cast-iron is cheap enough and that we should not seek to economize in the matter of thickness. But this may be the road to bring about the very catastrophe which we wish to avoid, owing to the unequal contraction of thick metal.

The writer refrains therefore from introducing any very dogmatic rule for guidance. But what we do know is, that the tenacity of cast-iron, such as that used in the north of England, may be taken as about 7 tons or 15,000 lbs. per inch, and that the bursting strain is in proportion to the diameter and the pressure; thus:—

so that the strain upon a pipe 16 inches in diameter, when considered as a ring of a length of 1 inch, and at 100 lbs. pressure per square inch, is 1,600 lbs.; and to resist this pressure a thickness of 0.051 inch would be theoretically sufficient. But we have then to consider the factor of safety, which might be taken at $8\frac{1}{2}$ or 4,700



* *Boiler Explosions Acts, 1882 and 1890, Report of Preliminary Inquiry, No. 869, 2 pages and 1 plate.*

lbs., as the highest safe tension. Allowance must also be made for irregular thickness in casting, stresses due to shock, and bending stress from various causes, for which three times the actual pressure should be allowed, giving for factor of safety 10; and this would serve for water-pipes up to 100 lbs. pressure, as found in the case already alluded to.

For steam-pipes under similar circumstances the following formula is given, available for diameters of pipes up to 12 inches :—*

$$T = \frac{D.P.}{4000} + \frac{1}{2},$$

which gives a result of 0·9 inch.

It seems to the writer, however, that for a pipe 16 inches in diameter it would not be right to add less than $\frac{3}{4}$ inch, giving as a result 1·65 inches as the thickness of a pipe 16 inches in diameter at 100 lbs. pressure per square inch.

Water-Rams.—A further risk to which steam-pipes are exposed is that known as “water rams,” which may be thus described :—†

If steam be introduced below the surface of water contained in a large vessel a bubble will be formed, which will increase in size until its surface becomes sufficiently extended to condense the steam more rapidly than it can enter, when a partial vacuum will be created, and the water, flowing in from all sides at a high velocity, will meet with a blow forming what is called a water-ram. . . . The whole mass of water in the pipe is driven against the end, sometimes with sufficient force to rupture it.

Steam-pipes and Fire.—The fact that steam-pipes may be the cause of fire is one that is almost always overlooked, and indeed very commonly treated as an absurd suggestion, and this makes it all the more important that everyone connected with mines where a fire may have such terrible consequences, should be made aware of the risk and have it impressed strongly upon them.

To those who have any acquaintance with chemistry and the combinations of oxygen with carbon, and the absorption of oxygen by carbon, a little reflection will at once dissipate any doubt they may feel.

In order to understand the question we must first study the process of carbonization of wood, and afterwards its behaviour in the presence of oxygen or air.

Mr. Violette appears first to have studied the thermometric conditions or temperature necessary and sufficient to transform wood into

* *Practical Engineer Pocket Book.*

† *Proceedings of the Institution of Civil Engineers*, vol. cviii., page 481.

charcoal ; and he discovered that according to the method of carbonization he could obtain 15 to 40 per cent. of charcoal, and that the two kinds of charcoal so obtained differed in their chemical and other characteristic properties. He found that at a temperature of 392° Fahr. the wood did not carbonize, and that only at 570° Fahr. could he invariably get good black charcoal.

Mr. D. K. Clarke says that * under temperatures up to 300° Fahr. the wood is simply desiccated, and above that the gaseous elements are driven off until at 650° Fahr. the wood yields a charcoal which is black, solid, and brittle ; and as the temperature of steam at a pressure of 50 lbs. per square inch above the atmosphere is not more than 298° Fahr., it is clear that when we find wood carbonized by steam at this pressure, it is the effect of prolonged action of heat with which we have to deal.

It appears, therefore, that the temperatures to which Messrs. Violette and Clarke refer, may be considered as the immediate process, which gave a result in from $\frac{1}{2}$ to 3 hours, but the prolonged exposure of wood to a much lower temperature will eventually produce the same result.

Dr. Percy says : " The lower the temperature at which charcoal is produced, the more powerful is its power of absorption." † It is also a well-known fact that such charcoal as is produced at a low temperature is much more subject to spontaneous combustion than that which is produced by a higher temperature.

In *Engineering*, it is said :—

It is well known that the ignition-point of charcoal bears a certain ratio to the temperature of carbonization ; the lower the temperature the more readily combustible is the charcoal, and this fact is made use of in producing charcoal for the manufacture of some grades of gunpowder by means of superheated steam. ‡

The case is precisely the same as the prolonged action of heat upon coal.

Prof. Vivian B. Lewes wrote :—

It has been pointed out that if coal be kept at a high temperature, even though it be far below its igniting-point, ignition is only a question of time ; and if the bunker coal . . . be kept at 120° Fahr., any coal with a tendency to absorb oxygen will run a great chance of igniting within a few days.§

In the discussion upon this paper, Mr. W. E. Stanley Thompson said :—

That Commission called special attention to a paper by Sir Frederick Abel and Dr. Percy, explaining scientifically the cause of spontaneous combustion, in which

* *Manual of Rules, Tables and Data for Mechanical Engineers*, 1877, page 445.

† *Metallurgy: Fuel*, 1875, page 363. ‡ 1887, vol. xliv., page 580.

§ *Journal of the Society of Arts*, 1892, vol. xl., page 363.

a great deal of space was devoted to the part taken by pyrites, though later on they also explained that coal itself was liable to oxidation, and after explaining the process, they expressly said that this oxidation of the coal was one of the causes, if not the chief cause, of spontaneous combustion.*

Prof. Vivian B. Lewes further said:—

Carbon is one of those substances which possess to an extraordinary degree the power of attracting and condensing gases upon their surface, this power varying with the state of division and density of the particular form of carbon used. . . . The absorption is at first purely mechanical, and itself causes a rise of temperature, which, in the case of charcoal formed in closed retorts, . . . would produce spontaneous ignition if it were not placed in sealed cooling-vessels for some days before exposure to the air. . . . When coal or charcoal is finely powdered, the exposed surface being much greater, absorption becomes more rapid and rise of temperature at once takes place. If charcoal is kept for a day after it has been made out of contact with air, and is then ground down into powder, it will frequently fire after exposure to the air for 38 hours, whilst a heap of charcoal-powder of 100 bushels or more will always ignite.†

At collieries, of course, the same precautions should be taken against coals, especially small coals, coming into contact with steam-pipes, as is necessary in the case of wood, although the absorption of oxygen is only about one-third of that of charcoal.

The idea that pyrites was the source of spontaneous ignition in coal cargoes had been successfully combatted by Prof. Vivian B. Lewes, and the oxygen-absorption theory established in its stead.

Of course everything that had been said as to the danger of steam-pipes near wood or coals about a colliery, applies with equal force to them when used for warming houses or other buildings, thus:—

A mill in Providence, Rhode Island, was burned by a fire originating from the steam-pipes in an unlooked-for manner. At the time of its construction the proprietors exercised great care that all pipes should be free from direct contact with the woodwork, but when the steam was let into the pipes the expansion increased their length and pushed their ends against the wooden partition which was eventually set on fire.

It remains only for the writer to produce a piece of wood which was found actually on fire from contact with a steam-pipe used for conveying steam to an engine in some workshops, and to express a hope that no wood will hereafter be allowed to touch steam-pipes, many hitherto unexplained causes of serious fires being thus explained.

* *Journal of the Society of Arts*, 1892, vol. xl., page 362.

† *Institution of Naval Architects*, 1890, vol. xxxi., page 205.

Mr. JNO. J. KING (Stanton) wrote that he had read Mr. Steavenson's paper with considerable interest. It had been generally understood that the rules applicable for the thickness of steam-cylinders were also suitable in the consideration of the strength of steam-pipes. Most engineers in charge of mines had therefore had before them, for many years, formulæ to guide them, in addition to their experience. The formula used by Mr. Steavenson, $T = \frac{D \cdot P}{4,000} + \frac{1}{2}$ had been in existence a long time in *Molesworth's Pocket Book* under the heading of "Loco Steam Cylinder Thickness." Of course in using this formula for cylinders allowance is always made for boring and wear. *Hutton's Works Managers' Hand-book*, 1890, in discussing the question of thickness of steam-cylinders, pipes, and tubes subject to internal pressure, gives a reliable formula as under:—

$$T = \frac{P \times R}{2,500} + C,$$

where P is pressure in lbs. per square inch ; R, internal radius of pipe ; C, a constant to cover shocks, irregularities of casting, bending weights, etc., varying from 0.13 to 1.0 according to class of work and size of pipes.* Mr. Hutton bases this formula on the assumption that average cast-iron in pipes and cylinders will not break under a stress of 15,000 lbs. per square inch, and takes a factor of safety of 6 (thus $15,000 \div 6 = 2,500$ lbs. as the safe stress).

Prof. Unwin in *Machine Design* states that the thickness of steam-cylinders and pipes can be calculated by rules given on previous pages, and embodies these in a table.† From this statement it is seen that a pipe 16 inches in diameter for 120 lbs. pressure requires theoretically a thickness of 0.560 inch. This table is based on a breaking stress of 18,500 lbs. per square inch for cast-iron, and a factor of safety of 10, giving 1,850 lbs. per square inch as the safe stress. This thickness, then, agrees fairly with the result obtained by Mr. Steavenson, but he agreed that this value was quite inadequate in practice, requiring the addition of an amount for shocks, etc. Mr. Hutton's formula gives for a pipe 16 inches in diameter at a pressure of 100 lbs. per square inch, 1.32 inches as the thickness required, C being taken at 1. He adopted this constant because he considered, with Mr. Steavenson, that 0.5 was not sufficient in the case of large pipes. He thought that Mr. Steavenson's thickness of 1.65 inches was somewhat over the mark as against Mr. Hutton's, being an increase of $\frac{1}{4}$ inch. He was frequently specifying thicknesses for steam-pipes in

* Page 101. † Page 155.

the way of business, and had adopted a scale for his own use which had proved suitable for various pressures. The thicknesses were shown in the following table :—

Pressure in Pounds per Square Inch.	DIAMETERS OF STEAM-PIPES.					
	4 Inches. Inch.	6 Inches. Inch.	9 Inches. Inch.	12 Inches. Inch.	15 Inches. Inch.	18 Inches. Inch.
50 ...	$\frac{1}{2}$...	$\frac{2}{8}$...	$\frac{5}{8}$...	$\frac{3}{4}$...	$\frac{7}{8}$...	1 ...
75 ...	$\frac{3}{4}$...	$\frac{5}{8}$...	$\frac{3}{4}$...	$\frac{7}{8}$...	1 ...	$1\frac{1}{4}$...
100 ...	$\frac{7}{8}$...	$\frac{3}{4}$...	$\frac{7}{8}$...	1 ...	$1\frac{1}{4}$...	$1\frac{1}{2}$...
125 ...	$\frac{5}{8}$...	$\frac{7}{8}$...	1 ...	$1\frac{1}{4}$...	$1\frac{1}{2}$...	— ...
150 ...	$1\frac{1}{8}$...	1 ...	$1\frac{1}{4}$...	$1\frac{1}{2}$...	— ...	— ...

Of course, in using this table, he assumed that engineers would adopt all necessary precautions to prevent priming into pipes, would provide adequate drainage for condensed steam, and that provision would be made for the expansion of long ranges of steam-pipes.

It appears to him that the old-fashioned packed expansion-pipe did not prove satisfactory ; either it lost steam through glands being left loose, or if they were screwed tight enough to prevent such leakage, then expansion was hardly possible, and consequent lifting and straining of the pipes occurred. Corrugated copper expansion-pieces have not turned out as efficient as anticipated, the material and mode of treatment proving rather inelastic than yielding, owing, he thought, to the number and smallness of the corrugations. Nothing could equal a pair of thin copper dished discs of large diameter, when inserted in the range of pipes ; they were really elastic and flexible to a high degree.

A vote of thanks to the writer of the paper was adopted.

The following paper by Mr. H. W. Ferd. Kayser on "Tin-mining in Tasmania" was taken as read :—

TIN-MINING IN TASMANIA.

By H. W. FERD. KAYSER.

The history of tin-mining in Tasmania begins from the latter part of 1871. It was a very small beginning, probably on account of no one knowing anything about the business, or perhaps the people had not forgotten the lesson taught them in their earlier mining undertakings, and they did not feel particularly anxious to repeat the folly of the past in trying to become rich all at once.

The colony was in a desperate condition at this period, and Victoria, the market for Tasmania, had been almost lost, partly through the competition of New Zealand and South Australia ; but the principal loss was caused by the introduction of the Victorian protective tariff, and something had to be done to lift the credit of Tasmania to its former level. This was no easy task, but once the mining industry properly started with a fair prospect of success, many willing hands came forward to seek both fame and riches.

Mr. James Smith, known also as the "Philosopher," had been out prospecting for many years, with the expectation of finding gold-fields in Tasmania similar to those he had seen in Victoria, but fate in this respect was against him, and after years of hard toil in overcoming the difficulties of scrub and climate, he eventually returned from the wilderness on December 4th, 1871, with a matchboxful of something, nobody knew what.

It was soon ascertained that the contents of the box was tin-ore, but this was a great disappointment to those most directly interested, as any other metal better known, like gold, silver, or copper would have made a far greater impression than what was conveyed by the name of tin.

However, this idea did not last for long, nor did it keep the adventurous and hardy prospectors out of the bush, and during the summer following tin-ore was discovered on the east coast in different places, but so far not in payable quantities.

Mr. James Smith's discovery was made in the Tinstone creek, a tributary of the river Arthur, at the foot of Mount Bischoff, on the

north-western coast, and although a number of prospectors followed his footsteps it is also evident that other parts of the colony received a fair share of the prospectors' attention ; hence the early discovery of the same ore on the eastern and north-eastern coasts of the island.

Many parties were out prospecting, and credit must be given to Messrs. G. R. Bell and party to be the first to take up leases at Thomas Plains on May 22nd, 1875. This ground proved not only payable, but very rich in ore.

Thomas Plains where the first leases were applied for and active work started, is about 45 miles from George's Bay. The greater part of the district was heavily timbered and scrubby country, quite unfit for road-making in those days, on account of local circumstances.

It was difficult enough in the first instance for the prospector to find his way through the wilderness, but when a rush followed it was not only necessary to get provisions up to the mining-camp, but also to find ways and means of taking the ore to the market.

At this particular time, the colonial exchequer being low, but scant assistance could be expected from that quarter until the stability of the industry was proved beyond a doubt, and then only mere make-shift tracks were constructed. Many of the parties who were working in these early days could not or would not wait for the government to construct these packhorse tracks, and rather than lose the season, constructed them themselves.

While the Thomas Plains parties were at work, other parties went farther ahead, and one district after the other was found and opened up : the Blue Tier on the one side, and the Ringarooma and the Winiford rivers on the other, besides numerous creeks and tributaries, all carrying payable tin-ore.

Some of these claims turned out remarkably rich, and one in particular on the Ringarooma river, called the Brothers Home, belonging to Messrs. Krushka Brothers, is worthy of notice. This claim has been working about 20 years, and, according to information received, must have yielded to its fortunate owner at least £250,000 for the tin-ore extracted.

Later on tin-ore was discovered at Mount Heemskirk, both in alluvial and in lodes, but so far it has not turned out very successful ; the same may be said of the Pieman river field. Tin-ore is also known to exist in small quantities on Bell Mount, between the river Forth and Wilmot. Here the tin-ore is associated with bismuth ; at Housetop and Whales Head alluvial tin-mining is also carried on, on a small scale ; at Ben

Lomond, and at Brookstead in the Avoca district, and many other places in that locality, viz., Rex Hill and Roy Hill, where some very rich deposits have been worked.

The latest discovery has been made at Dundas, on the Ring river. This deposit is stated to be very promising, but on account of its being highly charged with iron and arsenical pyrites, all the ore will require calcination, and being situated a long distance from any point of communication, its development will take some time.

The largest extent of tin-ore deposits consisted of river, creek, and flat washes, easily worked by hydraulic sluicing, and for that purpose the miner availed himself of the running stream by cutting a race for bringing the water to the place of operation; also cutting a tail-race for taking away the tailings. In the early days, when only the low-lying and shallow ground was manipulated, the work entailed but little expense; but later on, when the shallow ground became exhausted and the tin drifts were followed into terraces, more elaborate water schemes had to be undertaken. In some instances, thousands of pounds had to be expended before the tin-wash could be profitably handled; in other instances, this expenditure was necessary to bring poor ground to a payable condition, and to work the quantity where the quality was not obtainable.

This statement applies particularly to the Mount Cameron district, where in latter years nothing but poor ground has been available, and to bring in sufficient water to benefit the workers was more than private enterprise could undertake. On that account, the government and parliament sanctioned the necessary expenditure, and constructed a race large enough and of sufficient elevation to supply with water all owners of claims who wished to use it at a certain rate per sluicehead. This rate is fixed by a sliding scale according to the rise and fall of the tin market.

The total expenditure for this work amounts to £33,286. The number of sluiceheads supplied during 1895 amounts to 6,228, the income for the same year being £886 18s. 8d., and the rate of interest upon the cost of purchase and construction amounts to 1·012 per cent. This rate does not show to any great advantage, but when we take into consideration the very low price obtained for tin-ore during late years, better results may be anticipated so soon as the condition of the metal market improves.

Smaller undertakings are carried out by co-operative parties and companies in numerous instances, and large expenditures can be undertaken only in cases where the extent of ground held under lease is large enough to justify such an outlay.

The writer believes that the next largest undertakings are those of the Briseis, Brothers Home, Brothers Home No. 1, and the North Brothers Home companies. All these companies have cut races and built flumes for many miles in length at high elevations, so that they can work their ground by hydraulic-sluicing under high pressure.

All the different companies just mentioned are working on the leads known as the Cascade and the Ringarooma, but there is a strong belief that a branch is turning westward through the ground formerly prospected by the Ringarooma Tin-mining Co. As, however, the ground deepens very fast after it passes the Brothers Home lease, and gets below the level of the river, it was more difficult to work, and for this emergency the companies working this deep ground were not prepared, and consequently their existence turned out to be a very short one, barely sufficient work being done to prove the stanniferous value of the ground.

With the exception of the Brothers Home, and part of the Briseis Company ground, none of the deep-lead companies have done any good for themselves except that they have proved that payable ore exists in the deep ground, but as their equipment for working this kind of ground was not suitable, one company after the other came to grief, as shareholders soon got tired of paying calls, when the prospects for dividends were so remote as they were in this particular instance. However, it is to be hoped that, as soon as the price of tin-ore recovers in value sufficiently to leave a profit on working expenses, a start will be made to work these large deposits, as there is an unlimited amount of ground to operate upon, with every probability of being highly profitable if properly worked. The open-face and hydraulic system is very good and economical, and preferable to any other system under certain conditions; but as soon as the bottom, which carries the best of the ore, dips under foot, it becomes a matter of cost whether the hydraulic system should be kept on or some other means should be applied to recover the rich gravel from the deep leads.

If the work be faced in a business-like manner, there should be no difficulty in working the deep ground of the leads profitably, the only proviso being that the price of tin-ore must rise above the present figure.

So far as proved by different companies, the quality of the wash is good, and the quantity may be stated as unlimited; but if only 6 to 7 feet of the best wash is taken out, the result ought to be all that is desirable. The main points to consider are to have the main level well under the workings in solid ground, the pump to be able to manage the water, a winding-gear to haul not less than 500 tons in 24 hours, and the

necessary timber, which is plentiful, to keep the ground secure, while blocking is carried on from rise to rise, which are connected with the main level.

The Cascade lead, whose origin is high up in the ranges, and begins almost at the surface, is getting deeper and deeper as it advances in a northerly direction, and by the time it reaches the Brothers Home boundary the depth is nearly 70 feet. Here the bottom of the lead is still above the level of the river, but by the time it crosses the river into the North Brothers Home ground the bottom is considerably below the level of the river, while the face is fully 145 feet high in the highest part, consisting of a basaltic capping, in places over 20 feet in thickness, light gravels with cement veins running horizontally at intervals, and about 10 to 12 feet of stanniferous gravel. The bottom of the lead is dipping fast, and on this account the bottom wash has not been worked. Different attempts have been made to prove the value of the wash in the middle of the gutter, but all have failed. The last prospecting works carried on in this particular place have proved a false-bottom over 12 feet in thickness, but during the time this work was in hand a heavy flood in the river destroyed everything, and no other attempt has since been made to get to the bottom wash in this company's ground. The only proof to hand at present in its favour is that the shallow ground at the edge of the lead, both east and west, where the false-bottom thins out, is found to be very good and from 6 to 7 feet in thickness, but the gravel is of a different colour and character from those of the wash on the false-bottom in the adjoining company's ground. This high-reef ground has been proved by the Triangle Tin-mining Company, and although the dirt taken out has been very good, the result is not what might have been expected from both quality and quantity treated. This can be easily accounted for when we take into consideration that the workings are below the level of the river, and the appliances for doing the work and unwatering the ground are of the most primitive kind.

The North Brothers Home Company adopted the hydraulic system under the greatest advantages by having high pressure and unlimited water, nevertheless they have found that the proportion between the pay dirt and overburden were not such that payable results could have been expected. This can be easily seen when we look at the fact that for about 10 years of working time only 966½ tons of black ore have been produced. The other known deep lead is that of George's river, not many miles from George's Bay, a very nice watering-place for tourists during the summer season ; but very little of the value of this lead is known, except

that some shallow workings have been kept going for some years. These works have been carried on generally by working miners, and little is known of their doings. According to Mr. Montgomery, government geologist, these deposits belong to the Miocene and more recent age.

These leads must be looked upon as the great storehouse of the future mining industry of the colony, and as soon as a proper method for working them is adopted, with a fair price for the tin-ore, no one can say what results may be achieved.

The Blue Tier is situated between the deep leads of the Ringarooma and George's rivers, and deserves mentioning on account of its richness and its high elevation. The writer believes that it is the most elevated tin-drift worked in the colony, as the Tier is about 2,500 feet above sea-level, and in the early days, in spite of its climatic drawbacks, this not extensive district stood very high as a tin-ore producer. The most elevated part of the Tier is not very extensive, and the companies that were fortunate enough to secure leases in the early days were well rewarded for their outlay, but since the alluvial deposits have been worked out the tin-ore production has greatly fallen off.

Different attempts have been made to work the dyke-stone found after the removal of the alluvial, which contains a small percentage of tin-ore (from $\frac{1}{2}$ to 1 per cent.), but so far no one has been able to work this deposit profitably, and it is to be hoped that the attempt now being made by the Anchor Tin-mining Company will turn out more successful than that of its predecessors. It is not an easy task to make this low-grade ore pay, even when worked on a large scale and with good machinery, and the greatest economy will be required to carry this undertaking to a successful issue. The result of this company's operations will be watched with great interest by all tin-miners in the colony.

All the dykes in this district are more or less stanniferous, but unfortunately the tin-ore appears to decrease in depth as the ground becomes harder, and it is a pity that none of the companies interested in this district have taken the advice so often given to try the deep ground with the diamond-drill, and thereby settle the question of permanency or otherwise. A large amount of money has already been spent, or one may say wasted, in trying to prove the value of this formation, but so far no good results have been achieved.

All the formations of the stanniferous zone on the eastern and north-eastern coast are granite or porphyritic granite, but in no other locality does the writer know of dykes of the same character and of the same extent as in the Blue Tier district. In most instances the soft bottom,

below the wash, has been worked by ordinary hydraulic sluicing with very fair result, but all attempts with machinery have failed, partly, the writer believes, on account of the ground becoming poorer in depth, and very likely the machinery selected to treat the ore has not been at all suitable.

There is abundant evidence of the existence of dykes in other localities, but they differ in some respect, particularly from those at Mount Bischoff, but as the writer wishes to treat the Mount Bischoff mine by itself, he will say no more about it at present.

The tin-lode formations in the colony have not, up to the present, received the attention which they deserve, partly on account of the alluvial being plentiful and so easy to work, while lode-mining is more costly and requires skill, which is only obtainable in the trained miner, hence so little has been done in this particular branch of the industry.

Numerous lodes are known to exist in the stanniferous districts of the colony; from George's river right up through eastern and north-eastern coasts, also at Mount Heemskirk, at the North Pieman river, at Belmont, between the rivers Forth and Wilmot, at the west coast, at Ben Lomond, at Brookstead in the Avoca district, and at Mount Bischoff, but from the whole number mentioned only very few have been worked successfully, and then only for a short time.

In the near future, particularly if tin-ore should rise in value, all the lode-formations in the different districts will also become of great value to the mining industry of the colony. In the Avoca district, Brookstead with its numerous lodes, and Roy and Rex Hills, all close to the railway, while others further inland have also the great advantage of being able to secure water-power for all requirements. All these advantages are of great value, and although some of the lodes may not be rich, still with cheap motive power, good machinery, and systematic management, and provided they can be worked on a large scale, they should turn out successful, and at the same time offer an opening for capital to assist the working miner.

In too many instances local conditions have been overlooked or neglected, and consequently the mine gets the blame instead of the management. The only way to carry on mining successfully is to appoint a manager who is able to take the responsibility of his position, and directors, if they are wise, will never interfere in the actual management of a mine, as it is impossible for any gentlemen, however practical they may be, to instruct a manager how to work a mine, especially if they cannot be always on the spot, and it is more than folly if both these conditions are wanting.

The writer is pleased to say that this defect is noticed by all observant

mining engineers, and no doubt it will be corrected, as far as possible, in the near future by all companies who are willing to pay a manager an adequate salary.

So far, the writer has treated the mining industry of the colony as a whole, but as the Mount Bischoff Tin-mining Company is a sufficiently large concern, and of great importance not only to this colony, but to the tin-mining industry in general, it requires, he hopes, no apology to treat it by itself, particularly as the discovery of this mine started the industry, and as the writer had been connected with it for over 21 years.

The mine is situated $47\frac{1}{2}$ miles inland from Emu Bay, on the north-western coast of the colony, a township of no consequence before the discovery of this mine, but which has since become of some importance. The farming in the early days around the coast was greatly neglected, as the produce had no value, or very little, to the settlers of the district; but as the mine developed it was only natural that the surrounding districts should benefit in proportion. In those days the name of "road" was unknown, exactly as in the other tin-mining districts. The only means of communication was kept up by pack-horses. Later on, the several companies having interests in the locality subscribed £10,000 to improve the track, so as to be able to use it for vehicular traffic during the summer time.

Taking this difficulty into consideration, it is no wonder that the development of the mine did not progress very fast. The same drawback just observed to secure communication with the coast made itself felt at the mine itself. A thick forest of myrtle and horizontal scrub covered the ground between the river Waratah and the mine, about a mile apart, and as there was no permanent water at the mine it was necessary to connect these two places by a tramroad, originally constructed of wood, to bring the dirt to the river for washing purposes.

During the preliminary work of building the tramroad, erecting sheds, and connecting the sheds with the river by race and flume, part of the mine was cleared of the timber, so as to be able to get at the washdirt. In the meantime, during the winter, all available water at the mine was used for sluicing, to concentrate the ore as far as possible. But it was soon found that the process adopted was not a payable one, and therefore it was necessary to look about for some method of working, which would promise to leave a small margin of profit. It must here be remarked that by this time nearly four years had passed away, and the shareholders of the company began to grumble, as promises held

out at first had not been realized, and they did not know whether it was the fault of the mine, or the management, or both. However, considerable work in the development of the mine had to be done before better results could be expected. As already stated, the carrying of the dirt from the mine to the river could not be carried on with profit, and therefore other ways and means had to be adopted to improve upon the old system. A large reservoir was built at the mine, in a suitable position, to store all the water possible which the copious rainfall of the district provided, and in the following winter (1876) eight sluices were at work. This number was increased from year to year, until the number of sluices had increased to 32. This large number could only be worked by a system so arranged that the water from the one set of sluices was available for the next set, and as the working-faces were situated on the slope of the hill, and the reservoir above them, this system answered admirably.

The concentrates from these sluices, containing about 20 per cent. of tin-ore, kept the sheds employed for two shifts per day, but as the mode of ore-dressing then carried on was of the most primitive Cornish style, no objection could be made for the length of time it required to do the work. In spite of all these drawbacks, the directors were able to declare the first dividend of £12,000 in February, 1877, and from that time forward the dividends have been as regular as the months in the year.

This company possesses seven 80 acres sections, and one 40 acres section held under lease from the crown at the original rental of 5s. per acre, but at the expiration, some years ago, of the first lease (21 years) the government imposed a penalty for renewing the lease of the two most valuable sections in a sum equal to seven times the original rent, or 35s. per acre.

The formation of the Mount Bischoff mine is peculiar, and comprises, perhaps, the greatest variety of deposits at any one mine. The southern section was covered over to a large extent with coarse and heavy waterworn porphyry detritus, in one place over 70 feet in depth, all of which carried free tin-ore more or less, besides the stone and tailings containing sufficient ore to be worth crushing. The Slaughter-yard and Brown faces on the northern section contain large gossan-formations, besides porphyry detritus, but the formation of the two faces differs in many respects, except that all carry tin-ore, and by judicious mixing a payable percentage is maintained. The greatest difference in these two deposits is that the Slaughter-yard face shows iron pyrites already in shallow ground, while the Brown face deposit is almost free of this to a depth of over 200 feet, but

curiously enough large iron pyrites-formations are to be found outside of the gossan on the western, eastern, and southern sides, while the northern side rests against slate. The origin of these huge deposits appears to be a puzzle, as no two geologists have been able to agree upon all points in connexion with it. Therefore, there is still a good deal of work to be done before the geologist is able to say that the deposit is of a hydrothermal origin, or that it was part of a deposit of a pyritic formation which had gradually decomposed and was left in the state wherein we find it at present.

The Brown face is undoubtedly an isolated deposit resembling in many respects a stockwork, but not in others, and it is still a point of speculation whether we shall cut a new formation below the 260 feet tunnel, where the formation thins out in veins, carrying both tin-ore and iron pyrites. But so far as this deposit has been worked (about half that depth) it has been in places very rich, and if worked by itself would average about 5 per cent.

The Slaughter-yard deposit points more to a hydrothermal origin, and must be of a more recent age. The writer's reasons for this opinion is the large extent of iron pyrites in the shallow ground, and the existence of native sulphur in one part of the excavation. This occurred about 24 feet below the surface, and was found in small crystals in white quartz sinter, with payable tin-ore both below and above. This face has also produced, and is still producing, highly payable ore, but in some parts contains a higher percentage of silica than any other gossan at the mine.

Of lodes, we have several in the different companies' grounds, and the one worked by the West Bischoff Company gave payable results until the pyritic ores were met with. This occurrence, combined with the low price of tin-ore, brought the mine to a stop. The same reasons apply to the Stanhope Company's workings, and also to the North Valley lode. The Queen lode is almost a cross lode to all the others. It has a strike nearly due east and west, is situated on the northern side of the Brown face, and is wrought both in the Stanhope and in the Bischoff Company's ground for a distance of about 1,675 feet. The eastern end in the Stanhope Company's ground has broken through the porphyry-dyke and continues through that rock and along it nearly to the eastern boundary-line of the Stanhope Company's ground. Before this point is reached it enters into the slate-formation, keeping the strike in a curved line with the hill, but loses in value further westward. This lode, so far as worked, varies from 1 to 5 and 6 feet in width, and contains from 5 to 50 per cent. of black tin.

Having described these formations, there is still one left, namely, the porphyry (eurite) dykes, and as these dykes have had a great influence upon our tin-formations, the writer will say a few words about them. The plan (Fig. 1, Plate XXIV.), made some years ago, shows the dykes, etc., known at that time. These dykes have broken through the Silurian slate and sandstone and traverse them in different directions; they are stanniferous in the tin-ore bearing zone, but beyond that line they become barren and change in character altogether. In some instances, the intrusion of these dykes has folded and twisted the schists in remarkably pretty anticlinal sections when exposed by excavations or cuttings, but these sections show in many places a long way off the eruptive rock, or they may indicate that this rock is only a short distance beneath the surface (Figs. 2 and 3, Plate XXIV.).

The porphyry, generally called quartz-porphyry, contains, as a rule, a small amount of topaz, either massive or in small crystals, discernible particularly in little cavities. Only in one instance has a pure topaz dyke been discovered, and that occurred on the southern section of the Mount Bischoff Company's mine. It is about 3 feet in thickness where opened and may contain on an average about 10 per cent. of black ore. This dyke cannot be worked at present, as it would interfere with the workings of the mine. This is only one instance of many where small lodes or ore veins are known to exist, but cannot be worked for the same reason.

These dykes ramify the whole mountain, and show on the surface for a long distance, but they become more concentrated within the workings of the mine. They contain from a trace to patches of remarkably rich ore, but the writer believes that the average does not exceed more than 1 per cent.

All the principal works are carried on by the open-cut system, and when one level is exhausted a second is started, or, as at present, two levels are worked simultaneously. The faces are all connected by double tramroads, on which half-ton trucks are used. Stone and crush-dirt passes are connected in a similar way with the stone-breaker and the passes from which the railway-trucks are filled, so that double handling is as much as possible avoided. The height of the upper tramroad from the level of the railway is about 120 feet. The railway which connects the mine with the Waratah sheds is about $1\frac{1}{2}$ miles in length, and with a 12 horse-power locomotive running 8 hours per day, 75 stamp-heads are kept constantly at work. All stone passes through the stone-breakers at the mine.

At the sheds, nearly the whole machinery is automatic, and works cheaply and efficiently. The batteries of 5 stamp-heads each reduce the crush-dirt to sand, which passes through steel-wire screens of 196 holes to the square inch, thence into classifying-boxes (*spitzkasten*), two in a set, giving coarse and fine sands, which are conducted in pipes to the jiggers set apart for each class. The overflow from the classifying-boxes is carried by launders to the large settling-boxes. The residue from these boxes is drawn off and conducted in pipes to the revolving slime-tables, which produce first and second-class slime. The first-class slime is finished in the tossing-tub, while the second class is treated over again by itself. All overflow-water carrying float-tin is collected and dressed on a separate table. The amount thus saved is not large, but as the treatment costs almost nothing it increases the output and prevents a loss. The waste sand from the jiggers is taken to the concave-buddle to separate the real waste from the specimen-sand and the heavy iron ore; the latter is known to contain sometimes as high as 25 per cent. of black ore. These sands are afterwards reduced to slime in the Chilian mills in the ordinary way, and then treated on the revolving slime-tables.

All the motive power required for the Waratah works is furnished by water, only the air-compressor and the stone-breakers at the mine are worked by steam. In the sheds, there are 7 waterwheels at work on the different floors, so that the water from the first wheel can be used for the next one below, and so on to the last one. By this method over 200 horse-power is produced by waterwheels whose diameters range from 18 to 40 feet.

To secure all these advantages, large storage-reservoirs had to be constructed, as without them it would have been impossible, in spite of the heavy rainfall of the district, to keep all these works uninterruptedly at work. The expenditure for this undertaking amounts to £22,395.

For this water scheme, the Falls Creek, the Fossey, and the Waratah river have been laid under contribution. The two former creeks have been connected by race and flumes, and in favourable seasons the supply has been good, particularly since the large reservoir has been completed. This large reservoir is built of stone and cement 33 feet high, with the necessary strength of embankment, and when all the reservoirs, four in number, are full the waterline is about 7 miles in length, containing about 500,000,000 gallons of water.

The following particulars show the cost of mining and ore-dressing a ton of stanniferous material :—

Mining, including maintaining and other expenses	...	...	2	6½
Haulage, filling and emptying trucks, etc.	...	...	0	6½
Crushing and dressing, maintaining plant, etc.	...	...	0	11½
Slime-sheds, maintaining plant, etc.	...	...	0	2½
Management and supervision	...	...	0	8½
New works at the mine	...	...	0	2½
Plant, including all machinery (irrespective of situation), material, and stores	...	...	0	3½
Development and progressive works	...	...	0	1½
Ring-tail sheds, including removal and re-erecting plant	...	...	0	4½
Ore-bagging, including stores, etc.	...	...	0	0½
Engine-sheds, stables, charcoal, rates, and taxes	...	...	0	2½
Total cost, including stores	...	...	6	2½

The crushing power of the stamp-head is 4½ tons per 24 hours. The performance of each machine in saving the ore is as follows :—The coarse jigger sand, 44 per cent. ; fine ditto, 29 per cent. ; slime-tables, 23½ per cent. ; buddles, 1½ per cent. ; while nearly 2 per cent. is recovered in the slime-sheds. The quantity of ore produced to the end of 1896 amounted in round numbers to about 49,730 tons, for which nearly 6,000,000 tons of ore had to be reduced. The dividends to the end of the year, numbering 287, amount to £1,441,500, or £120 10s. per share besides the dividend tax of £48,050.

The total ore-production of the colony to the end of 1895 amounted to 75,281 tons of the value of £6,336,994.

The average percentage of the ore treated by the Mount Bischoff Company, after being mixed from all parts of the mine, reaches 2½ per cent., and this percentage enables the management to produce a little over 200 tons per month.

The rainfall for the last thirteen years averages 78·15 inches per annum.

In conclusion, the writer must not omit to thank Mr. F. Belstead, the secretary of the mines, for his kindness, both for giving information and supplying reports of those parts of the colony with which the writer was not personally acquainted, and thereby filling up a gap in his knowledge, for which he feels sincerely thankful.

The CHAIRMAN moved a vote of thanks to Mr. H. W. Ferd. Kayser for his interesting paper, and the motion was cordially approved.

The following "Note on Extensions of the Coal-field of the North of France," by Mr. M. Bertrand, was taken as read :—

To illustrate Mr. H.W.Ferd. Kayser's Paper on "Tin-mining in Tasmania."

GEOLOGICAL MAP OF MOUNT BISCHOFF

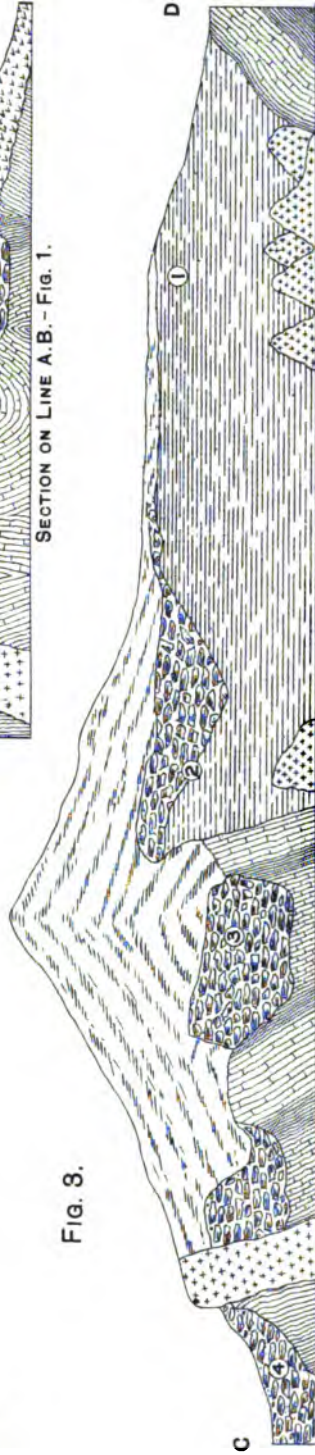
-  DILUVIAL.
-  DECOMPOSED METAMORPHIC DEPOSITS.
-  BASALT.
-  ① BROWN PAGE.
-  ② WHITE PAGE WASH.
-  ③ SLAUGHTER-YARD PAGE.
-  ④ WHITE PAGE.
-  NORTH VALLEY STANNIFEROUS QUARTZ LODE.
-  WHEEL BISCHOFF STANNIFEROUS QUARTZ LODES.
-  QUEEN STANNIFEROUS QUARTZ LODE.
-  RAILWAY.
-  ROADS.

Scale 1:125 Feet to 1 Inch.

FIG. 2.



FIG. 3.



NOTE ON EXTENSIONS OF THE COAL-FIELD OF THE
NORTH OF FRANCE.*

By M. BERTRAND.

The writer has not been able to get to know accurately of more than a small number of the boreholes made between Calais and Dunkirk, and as regards the recent discovery of coal near Wissant, he has only rumour to trust to. A series of borings have been commenced between Hard- inghen and Wissant.

There are, nevertheless, some general results which appear even now to stand out at least with a high degree of probability, and which, under certain reservations above mentioned, may be published. Between Dunkirk and Calais, it seems almost definitely proved that there is no Carboniferous formation. Almost everywhere the Upper Devonian has been found (with grits and red shales) in layers, which are generally lying at flat angles resting upon the edges of ancient phylloids of Silurian or Cambrian age. Near Calais, certain limestones have been met with, some of which are Devonian and others Carboniferous. The lowest portion of the Palæozoic synclinal would in this case be found near Calais, but in any case it is a synclinal of very small depth and comparatively flat, without any Carboniferous formation, and it becomes difficult to see in it the continuation of the Coal-measures of the Nord and of the Pas de Calais, as also that of Dover.

He, therefore, adhered to his opinion, which he had held for some time, that Hardingen was a prolongation of the Belgian coal-field. This field would thus show the two-fold character of being bounded at the same time by the extension of the Lower Devonian on the north and that of the Jurassic. Consequently, the Jurassic having been met with at Dover ought to belong to the same belt, which would lead us to suppose the existence in the Straits of Dover of a fault following approximately the line of outcrop of the Lower Cretaceous along the French shores and across the Straits.

This was the theory which had guided Mr. Gossélet, and in consequence of which the Wissant boring had been undertaken. This borehole had found Jurassic rock lying below the Cretaceous, and with Coal-

* "The Correlation of the Coal-fields of Northern France and Southern England," *Trans. Fed. Inst.*, vol. v., page 106.

measures below the Jurassic. It is not, however, a definite proof as yet, but it is nevertheless a remarkable confirmation of the idea which had guided this borehole. One must not overlook that there are difficulties of interpretation to be met. The supposed torsion of the Palæozoic rocks is very rapid and abrupt. The direction of the outcrop of the Lower Cretaceous is at the north of the curvature of the Boulonnais, whilst Hardingham is on the south. It is, therefore, necessary to await the result of new boreholes, to know whether the coal-field of Wissant is the prolongation of that of Hardingham, and whether the coal-field follows a uniform direction, exactly or approximately, with that of the Cretaceous lines on the surface. Upon the whole, there are thus two capital facts established: the absence of Coal-measures between Dunkirk and Calais; and the presence of Coal-measures at Wissant. To go further and discuss the connexions, we must wait until the borings are published.

DISCUSSION ON MR. H. HALL'S PAPER ON "THE COST AND EFFICIENCY OF SAFETY-EXPLOSIVES AS COMPARED WITH GUNPOWDER.*"

Mr. J. G. WEEKS (Bedlington) wrote that so far as the Bedlington collieries were concerned (and he thought that they were typical of the other steam-coal collieries in Northumberland) the matter had received careful consideration. Speaking with 25 years' practical experience of them, and backed up by his experience with the use of high explosives for several recent years, he (Mr. Weeks) estimated that to carry out the Home Secretary's Order as originally promulgated would, upon the basis of last year's workings and explosives used, have involved the owners, so far as cost of explosives, ignition, and shot-firing was concerned, in an increased expense of 2·58d. per ton. (In other words, what had cost under the existing system, without injury of any sort, 0·64d. per ton with blasting-powder would, with the prohibition thereof, and the substitution of a high explosive, viz., bellite, have incurred a cost of 3·22d. per ton.) To which extra cost of 2·58d. per ton was to be added a further cost of 3d. per ton loss to the owner if the use of the high explosive reduced the percentage of round coal by 5 per cent., as he (Mr.

* *Trans. Fed. Inst.*, vol. xiii., page 4.

Weeks) had reason to think would occur, and which figure was supported by Mr. Hall as being the result of certain hard coal collieries in Table I., viz., No. 4 colliery, where the lessened production of round coal amounted to 5 per cent.; No 9 colliery, where it was 4·95 per cent.; and No. 13 colliery, where it was 7 per cent.; and corroborated by Mr. Deacon as 5 per cent., being the result of his Derbyshire colliery.

There was also the fact unfortunately experienced that the use of a high explosive might involve a diminution of output per man per shift, and this had the effect of enhancing the cost of production, viz., an increased cost on the standing charges of a colliery with, in some instances, an increased tonnage to be paid to the workman. Thus the total increase to a coal company might be 6·5d. per ton, and this on an output of 1,000,000 tons would equal an extra disbursement of £27,083 per annum, very much too costly an amount for an alleged theoretically beneficial result. This amount would, whether all or in part, come off royalty rent, wages, or profit. It was not an easy problem to get it off any of these, and the most likely solution would be the closing of the pits and throwing out of employment in their own countryside of thousands of work-people.

The members would probably be told that the burden, like that of the Compensation Bill for injuries, at present before the House of Commons, had already been incurred by German and other foreign coal-producers; but he failed to see what comfort that would be to the British producer, when it took him, under existing conditions, all his time to hold his own, and to keep up his export trade at a bare profit, if any, to be told that in future he would be better able to do so by being thus additionally handicapped. Whether the imposition of the Home Office order arises from philanthropical or political considerations, the outlook is not good for either owner or workman, unless the order be considerably amended.

Mr. DONALD M. D. STUART wrote that Mr. H. Hall's paper in support of the Explosives in Coal-mines Order, 1896, prohibiting the use of gunpowder, was based upon returns from collieries yielding 5,000,000 tons or $2\frac{1}{2}$ per cent. only of the total output (exceeding 195,000,000 tons) for last year. He thought that an order of universal application could not be upheld upon such an insignificant basis. Statistics giving the relative cost and efficiency of gunpowder and high explosives upon an output of 5,000,000 tons were, however, interesting if they were taken upon an identical basis, to allow a comparison to be raised; but Mr. Hall's statistics did not comply with this condition. At Nos. 1, 3, 9, and 13 collieries the coal-screens in use when gunpowder was employed were

altered when high explosives were used, vitiating the basis of comparison of the yield of round coal by the two classes of explosive. At Nos. 5, 8, and 10 collieries, the returns are stated to include explosives for stone work, but Mr. Hall's subject was "confined to coal-getting,"* and consequently these returns are excluded. Gelignite, used at No. 7 colliery, is not a "permitted explosive," to which Mr. Hall limits his paper.† At Nos. 10, 13, 14, and 16 collieries, the cost of the gunpowder was unknown; the results of one explosive only are recorded at Nos. 11 and 12; and the yields of screened coal were not given at Nos. 8, 12, and 15, therefore all these returns failed to give a basis for comparisons of cost and yield of round coal. The remaining collieries, Nos. 2, 4, and 6, represent an output of 427,845 tons, less than 10 per cent. of the 5,000,000 referred to, and obviously a quantity of no value for considering the cost and efficiency of the explosives employed.

The particulars in Table I. indicate other disturbing elements in the coal-faces. This may be observed in the relative costs of explosives in soft, medium, and hard coal-seams, given in the following returns:—

					Cost of Explosive per Ton. d.
No. 3 colliery, soft coal	...	...	...	...	0·46
„ 6 „ medium coal	...	...	...	...	1·76
„ 1 „ hard „	...	...	...	...	0·34

Again, at 13 of the 15 collieries, the returns are the results for gunpowder used in the years 1882, 1885, 1886, 1887, 1888, 1891, 1892, 1894, and 1895, and the results for high explosives used in the year 1896, or in periods 1 to 14 years later. During these periods the coal-faces advanced to distant positions, where their capabilities of yielding round coal, and the quantities of explosive required, were necessarily altered. The returns are therefore due to different conditions in the coal-faces which destroy their value for purposes of comparison.

The statistics upon which Mr. Hall raises his conclusions are taken upon diverse conditions, which disallow a correct comparison; consequently his figures of relative cost and efficiency of gunpowder and high explosives, on the output of 5,000,000 tons, are of no value.

Mr. Hall's contention that permitted explosives will cost 0·31d. only more than gunpowder per ton of coal and yield 0·2 per cent. only less round coal,‡ is best answered by the following statement:—

In an important mining district, where the coal-getters are paid only upon the quantity of round coal passing over the screens, gun-

* *Trans. Fed. Inst.*, vol. xiii., page 5. † *Ibid.*, page 4. ‡ *Ibid.*, page 5.

powder has been disallowed, and the coal-getters compelled to use permitted explosives. It is stated on authority that the quantity of coal passing over the screens since the permitted explosives have been in use is so much less than when gunpowder was employed, that the coal-getters are getting 10 per cent. less wages. To this reduction of wages, the loss in reduced output of screened coal must be added, and a practical illustration is afforded of the serious increase in cost, and the diminished efficiency resulting from the prohibition of gunpowder and the substitution of permitted explosives.

Mr. Hall introduces the subject of safety of life upon a comparison between two out of the twelve mines inspection-districts, viz., West Lancashire and Northumberland. Table II. purports to give "the number of persons killed and injured by explosives (gunpowder, etc.)" as follows:—

	Northumberland Mines Inspection-District.			West Lancashire Mines Inspection-District.	
	Killed.	Injured.		Killed.	Injured.
5 years,* 1892-96...	12	160	...	3	50

* *Trans. Fed. Inst.*, vol. xiii., page 10.

If 1,000,000 shots be fired in one district and 4,000,000 in another, the accidents that arise may be estimated for comparison at four times greater with the 4,000,000 than with the 1,000,000 shots. Mr. Hall does not supply the number of shots fired in the Northumberland and West Lancashire mines inspection-districts during the period in which the accidents occurred, consequently there is no basis for comparing the figures in his table; and his conclusion "that by obstinate adherence to antique methods of mining, such as candles, gunpowder, and collier shot-lighters, a district, naturally safe, has become less free from accident than one naturally dangerous,"* is fallacious.

Returns have been prepared of the number of shots of gunpowder and high explosives, respectively, fired in the Northumberland district during 1896,† and the number of persons killed and injured by each explosive is recorded in the inspector's annual report. These records furnish complete evidence for establishing a comparison between the fatalities caused by gunpowder and high explosives. The records are:—

1896.			Shots Fired.
Gunpowder	...	...	4,328,618
High explosives	..	...	182,908

* *Trans. Fed. Inst.*, vol. xiii., page 11.

† *Colliery Guardian*, 1897, vol. lxxiii., page 489.

FATALITIES WITH EXPLOSIVES. *

	Gunpowder.		High Explosives.	
	Killed.	Injured.	Killed.	Injured.
Gunpowder	1	25	—	—
High explosives—				
Bellite	—	—	1	1
Detonators	—	—	—	2
Gelignite	—	—	—	3
	1	25	1	6

* Report of H.M. Inspector of Mines for the Newcastle District, 1896, page 12.

These returns indicate the following results :—

	Deaths.	Shots.	Injured.	Shots.
Gunpowder	1	per 4,328,618	1	per 173,144
High explosives	1	„ 182,908	1	„ 30,484
“Permitted explosives” ...	1	„ 182,908	1	„ 60,969

and upon these facts the conclusion arises, that had the “permitted explosives” been wholly used in substitution for gunpowder the consequence would have been 24 deaths and 74 injured men, whereas 1 death and 25 injured men was the actual result of firing ‘95-94 per cent. of the shots with gunpowder. It would be difficult to find more emphatic testimony to the superior safety of gunpowder as compared with “permitted explosives” than is furnished in the latest returns for the Northumberland mines inspection-district.

With this high record of safety secured, the description of the management of the collieries as “obstinate adherence to antique methods of mining, such as candles, gunpowder, and collier shot-lighters” by which the “district, naturally safe, has become less free from accident than one naturally dangerous” is another evidence of the nature of Mr. Hall’s statements about gunpowder, and of men who are personally responsible for the safety of their miners and collieries, whose only offence is that they are conscientiously following the teachings of actual experience in fulfilling their responsibilities to owners and men. Blasting in coal-mines is necessarily attended with some danger, but, before changing from an explosive thoroughly understood and of proved value, there should be unquestionable evidence that greater safety would be secured. Mr. Hall has for some years pressed for the prohibition of gunpowder with the authority and influence attached to his appointment. He has given assurances to successive Home Secretaries that the dangers incident to blasting would almost entirely disappear* if certain high explosives were used, and the employment of gunpowder abolished.

* Report of H. Hall, Esq., H.M. Inspector of Mines for the Liverpool District, 1893, pages 7 and 11; *ibid.*, 1894, pages 8 and 9.

The Home Secretary has stated recently that the “higher explosives” used “very generally all over Lancashire . . . have been found to be safe.” This impression is not in accord with the official reports, which give the number of persons killed and injured by explosives in the Liverpool and Manchester districts for 1896, as follows:—

	Higher Explosives.			Gunpowder.	
	Killed.	Injured.		Killed.	Injured.
West or Liverpool district ...	2	6	...	Nil	6
North and East or Manchester ...	Nil	2	...	Nil	4
	2	8	...	Nil	10

Obviously the Home Secretary has not been correctly informed, and is unaware of the fact that men are being killed and injured by the “higher explosives” used in Lancashire. The same experience is repeated in other district. The annual reports of H.M. inspector of mines for the United Kingdom for 1896 record the following deaths with explosives in coal-mines:—

HANDLING EXPLOSIVES, 1896.

	Gunpowder.			High Explosives.	
	Deaths.	Injured.		Deaths.	Injured.
Gunpowder ...	18	158	...	—	—
Permitted high explosives—					
Ammonite ...	—	—	...	3	3
Bellite ...	—	—	...	1	4
Carbonite ...	—	—	...	3	14
Dahmenite ...	—	—	...	—	1
Roburite ...	—	—	...	1	4
Detonators ...	—	—	...	—	5
Non-permitted high explosives					
Gelnite ...	—	—	...	1	3
Gelatine dynamite ...	—	—	...	—	1
Cotton-powder ...	—	—	...	—	2
	18	158	...	9	37

High explosives therefore caused 33·33 per cent. of the deaths, and 18·98 per cent. of the injured men, though upon a reasonable estimate, they only formed 10 per cent. of the shots fired. Of these fatalities, the permitted high explosives were responsible for 30 per cent. of the deaths, and 16 per cent. of the injured persons, although they formed probably less than 5 per cent. of the shots fired.

EXPLOSIONS OF FIRE-DAMP OR COAL-DUST, 1896.

	Deaths.	Per Cent.
Permitted explosives (ammonite) ...	57	33·14
Gunpowder ...	20	11·63
Lamps and candles ...	95	55·23
Total ...	172	100·00

The annual reports of H.M. inspectors of mines show that permitted explosives caused 30 per cent of the deaths in handling explosives, and 3½ per cent. of the deaths caused by explosions of fire-damp and coal-dust. This is the latest reply, that the official records of experience in shot-firing in coal-mines supplies, to Mr. Hall's repeated assurances that loss of life by shot-firing would almost practically disappear, by the prohibition of gunpowder, and the compulsory, and universal adoption of "permitted explosives."

The loss of life by explosions of fire-damp in the Northumberland and West Lancashire mines inspection-districts respectively during the last 24 years, was as follows:—

24 Years, 1873-1896.	Northumberland Mines Inspection-District. Deaths.	West Lancashire Mines Inspection District. Deaths.
Explosions, by shots of explosives ...	61*	100
Explosions, by lamps or candles ...	34	318

* St. Helens not included. It occurred 12 hours after the shot was fired, and was due to a subsequent and independent course of action.

The output of coal during this period was:—

	Tons.
Northumberland district	365,126,142
West Lancashire district	509,662,669

The standard of safety in the two districts for the same period of 24 years, works out thus:—

	Northumberland. Tons (Round Figures).	West Lancashire. Tons (Round Figures).
Quantity of coal raised per life lost in explosions by shot-firing ...	6,000,000	3,000,000
Quantity of coal raised per life lost by explosions with lamps and candles	10,000,000	1,000,000

In the face of these official facts, it appears unnecessary to offer further comment upon Mr. Hall's description of the management of the Northumberland mines inspection-district as "antique methods of mining, such as candles, gunpowder, and collier shot-lighters."

Mr. HENRY HALL wrote that he had carefully read Mr. Weeks' further comments on his paper on the efficiency of safety explosives, and although it was impossible for him to check the costs he gives for Bedlington collieries he wished to point out to him a somewhat remarkable coincidence. Mr. Weeks had found that the cost for gunpowder blasting at Bedlington collieries was 0·64d. per ton. If he will refer to his paper, Mr. Weeks would find that the cost for gunpowder as deduced from Lancashire and Welsh collieries was stated to be 0·61d. per ton or almost

precisely the same as for the Bedlington collieries. Ought not Mr. Weeks to give him credit for being equally near the mark with his figures for safety explosives? Mr. Weeks in his original criticism said that "he had used bellite since 1892." He had too much respect for Mr. Weeks to think that without compulsion he had been incurring since that date an extra working cost of 6·5d. per ton, or that Lancashire coal-owners voluntarily incurred any such extra cost of working.

The following paper by Mr. W. Hamilton Merritt on the "Occurrence of Cinnabar in British Columbia, Canada," was read :—

OCCURRENCE OF CINNABAR IN BRITISH COLUMBIA, CANADA.

BY WM. HAMILTON MERRITT.

There is said to be but one cinnabar-mine under the British flag. It is situated on Kamloops Lake, near Savonas station, on the main line of the Canadian Pacific railway in the province of British Columbia.

It has been known for many years that the ore of mercury had been found in British Columbia, and the fact was mentioned by Dr. G. M. Dawson in his memoir on "The Mineral Wealth of British Columbia," published in the *Annual Report of the Geological and Natural History Survey of Canada*. Dr. Dawson stated that merely indications had as yet been found, and no workable quantity of the ore.*

Within the last few years, other discoveries have been made, and serious attention has been paid to the cinnabar-deposits in British Columbia. One company had commenced the development of a group of claims, and had recently constructed a Granza furnace to treat the ore. At the commencement of their operations only the high-grade ore was utilized, and the mercury was obtained by means of two retorts, which produced 114 flasks in all. It soon became evident that the great bulk of the cinnabar was disseminated through the formation carrying it, and that much the largest proportion obtainable ran somewhere about $\frac{1}{4}$ to $\frac{3}{4}$ per cent., according to the report of the superintendent, who estimated the capability of the mine, with one furnace treating its output, as follows:—

	Dollars.	£	s.	d.
Cost of mining (25 tons) and timbering per diem ...	40	8	6	8
Dressing and transporting per diem	8	1	13	4
Reducing	14	2	18	4
Superintendence and incidentals	10	2	1	8
Repairs, taxes, etc.	3	0	12	6
Total	75	15	12	6
Value of $2\frac{1}{2}$ tons of $\frac{1}{4}$ per cent. ore at 50 cents ...	125	26	0	10
Profit	50	10	8	4

* New Series, 1887-88, vol. iii., part 2, report R, page 106.

The more immediate object of this paper is to give some information about the actual occurrence of the cinnabar from personal observations, on the occasion of a short visit to the property by the writer.

The country-rock consists of a very dark-coloured basic lava, which is cut by dykes of other lava of a later origin and of a less basic type, the

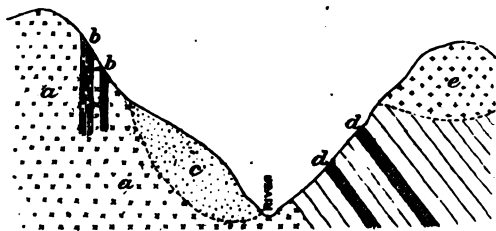


Fig. 1.—General Section of the Formation in an east-and-west direction.

latter being of a greenish-yellow colour. The dykes have been shattered and are traversed by veins and masses of dolomite which carry more or less cinnabar with it, and again the dolomite is cut by occasional veinlets of

pure cinnabar. The cinnabar is also found in the actual dyke-rock, but it more commonly occurs in the above-mentioned matrix.

Fig. 1 gives a general section of the formation in an east-and-west direction. In Fig. 1, *a* is the country-rock of dark-green basalt or augite-porphyrity; *b, b* are andesite-dykes (resembling bostonite) with dolomite-veins and cinnabar; *c* is alluvial gravel; *d, d* are trap-dykes; and *e* is porphyritic lava. The dykes cut the country-rock in two directions, running north 25 degs., east and north 20 degs., west (true meridian).

Microscopic examination of the country-rock shows that it is more decomposed than the dykes, but the latter exhibit a greater shattering influence. Fig. 2 is from a

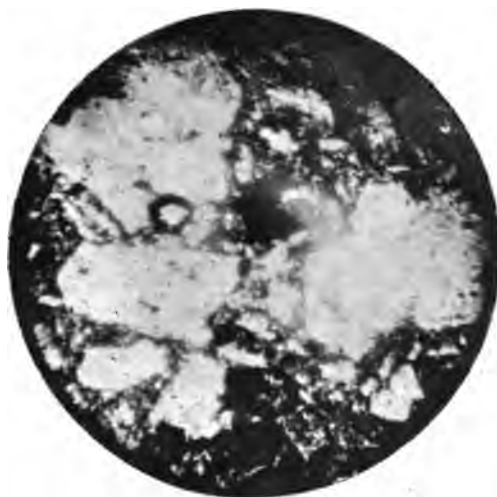


Fig. 2.—Country-rock of Basalt or Augite-porphyrity

photograph of a rock-section of the basic lava. It shows phenocrysts of augite (sometimes twinned) and plagioclase-felspar (the latter is partly replaced by calcite and kaolin) with a glassy matrix. The colour is dark green, and it is evidently a basalt or augite-porphyrity.

Fig. 3 is from a photograph of a rock-section of the dyke-rock.

Microscopic examinations show that this rock is a lava of an intermediate composition, namely, an andesite, consisting of a stained glassy or sub-microscopic ground-mass with phenocrysts of plagioclase-felspar (much decomposed) and dolomite or calcite. It resembles bostonite. The felspar-crystals are cut here and there by veinlets of dolomite, and there are occasional blotches of cinnabar. In some instances crushing force is shown by the disposition of the minerals.

It will therefore be seen that a dark green basalt or augite-porphyrity has been cut by dykes of less basic andesite-lava (bostonite?), and that



Fig. 3.—Dyke-rock of Andesite, resembling Bostonite.

these latter carry cinnabar chiefly in connexion with dolomite. The dyke shows internal evidences of fracturing, and the decomposed condition of the constituent minerals points to the possibility of the segregation of the cinnabar (which is seen diffused through the dyke matter) being the cause of the workable portions of the dyke. This leaching out and segregation would undoubtedly occur below, in zones of heat and pressure,

before the dyke was exposed at the surface. The shattered condition of the dyke, as shown by the veins of dolomite through it and by the veinlets of the same mineral cutting crystals in the rock, would indicate that there has been immense pressure exerted, that the dykes have proved lines of least resistance, as might reasonably be expected, and that channels were thereby formed through them for subterranean solutions.

The minerals found associated with the cinnabar are hematite and stibnite.

The PRESIDENT moved a vote of thanks to Mr. W. Hamilton Merritt for his interesting communication, and the motion was cordially agreed to.

THE FEDERATED INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,

HELD IN THE ROOMS OF THE ROYAL UNITED SERVICE INSTITUTION,
WHITEHALL, LONDON, JUNE 4TH, 1897.

MR. LINDSAY WOOD, PRESIDENT, IN THE CHAIR.

Mr. G. J. BINNS read the following "Notes on Borings at Netherseal, Ashby-de-la-Zouch, Leicestershire":—

NOTES ON BORINGS AT NETHERSEAL, ASHBY-DE-LA-ZOUCH, LEICESTERSHIRE.

By G. J. BINNS. F.G.S.

Some particulars of these borings have already appeared in the *Transactions*,* but as the time has now arrived when further details are available, the writer takes the opportunity of giving some account of the coal-seams met with in the bore-holes, and in the Netherseal colliery shaft, and of a fault, apparently possessing somewhat unusual characteristics, which intervenes.

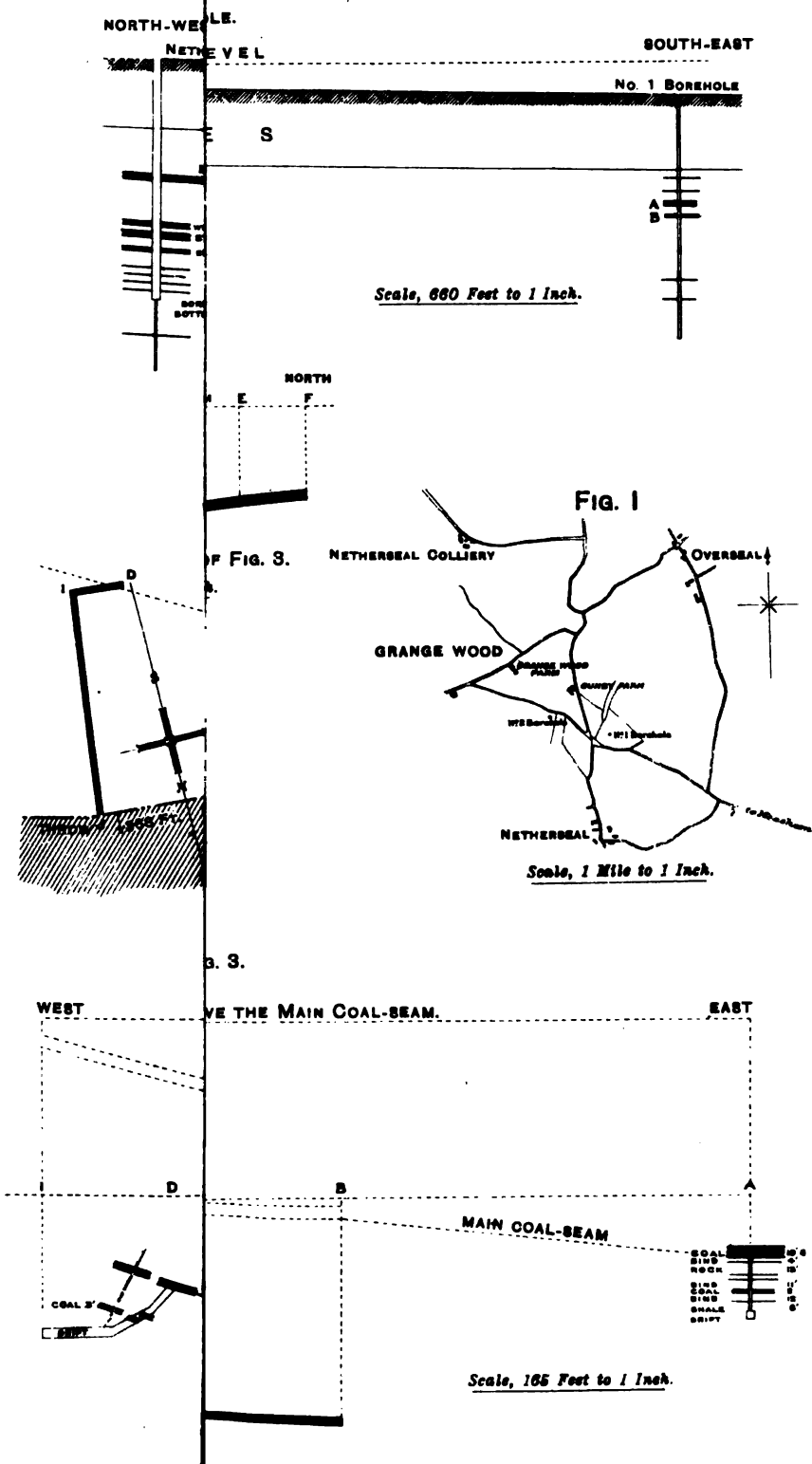
The Netherseal colliery shaft (Figs. 1 and 2, Plate XXV. and Appendix A) was sunk in the years 1866–70 for the purpose of working the Moira main coal-seam. As the area was at that time totally unexplored and some considerable doubt existed as to the probable depth of the seam, it was not recognized when passed through in the shaft, where it had pinched out to a thickness of 5 feet, instead of the 14 or 15 feet usually found in the district. The shaft was therefore continued through several seams to a total depth of 888 feet, after which a bore-hole was put down a further depth of 235 feet, making a total depth from the surface of 1,123 feet to a point where a rock, supposed to be of pre-Carboniferous age, was encountered. The bottom of this bore-hole yielded a strong feeder of water, heavily charged with hematite, but, unfortunately, there is at present no accurate detailed information available as to the surrounding circumstances.

* "The Discovery of a Concealed Ridge of Supposed Cambrian Rocks under the New Red Sandstone of Netherseal, near Ashby-de-la-Zouch, Leicestershire," by Prof. E. Hull, *Trans. Fed. Inst.*, vol. viii., page 90.

The section from the shaft to the No. 1 bore-hole is given in Fig. 2 (Plate XXV.); though much varied by faults, the general dip of the measures, so far as proved in this area, is to the east at about 1 in 9. At the point *J* (Fig. 3, Plate XXV.), a fault was found which put an end to further workings in that direction. The dislocation was supposed to be an upthrow to the south and explorations were accordingly made. Two coal-seams were discovered, which appeared to represent the stockings and eureka coal-seams, but, while the dip of the main seam on the northern side of the fault was to the east, the dip of these seams on the southern side was to the west. Under these circumstances, it became evident that a point could be arrived at where the throw would become *nil*, after which, if the fault continued, the dislocation would be a downthrow to the south instead of an upthrow. This eventually occurred. At a point *C* (Figs. 3 and 4, Plate XXV.), a chance drift from the main seam proved a seam 6 feet 2 inches in thickness, which was followed on the dip (in a direction almost exactly opposite to the seam just left) for 660 feet. This is believed to be the stockings coal-seam. At a point *A* (Figs. 3 and 4, Plate XXV.), a bore-hole was put up, which succeeded in proving 10½ feet of coal, and this is believed to be the main coal-seam.

It is considered by the writer that the seams *A* and *B* in bore-holes Nos. 1 and 2 represent the stockings and eureka coal-seams, in which case the main seam should have occurred at the point marked *C*, had it not been denuded (Appendices B and C.). The total thickness of Coal-measures appears in No. 1 bore-hole to be only 513 feet, and in No. 2 bore-hole, 472 feet, against about 840 feet in the shaft, while the post-Carboniferous rocks are 263 feet in No. 1 bore-hole, 281 feet in No. 2 bore-hole, and 251 feet in the shaft.

The influence of the fault at *J* on the position of the rocks found at the bottom of the bore-holes, has not, in the writer's opinion, been sufficiently considered. The difference in level between the surface at the shaft and at the bore-holes is 121 feet; the depth of Permian and Triassic rocks is 251 feet at the shaft and 263 and 281 feet at Nos. 1 and 2 bore-holes, so that the difference in actual level between the surface of the Coal-measures at the two points is 142 feet, the bore-hole being lower. The thickness of Coal-measures is, however, nearly 350 feet less at the bore-holes, which would be accounted for by an upheaval to the south of 368 feet, which is approximately the amount at the point *J* (Fig. 4, Plate XXV.). It appears, therefore, that the proximity to the surface of the rocks, classed by Prof. Hull as pre-Carboniferous, may be in a great measure due to this fault.



The want of resemblance between the bore-hole sections and anything known in the immediate locality renders the identification of the coal-seams extremely difficult. Supposing *A* and *B* (Appendices B and C) to be, as already suggested, the stockings and eureka coal-seams, then the Woodfield coal-seam (Fig. 1, Plate XXV.) appears to be entirely wanting, as is also the unnamed coal No. 26 (? Kilburn) in the shaft bore-hole (Appendix A).

APPENDIX A.—NETHERSEAL COLLIERY, DOWNCAST PIT.

No.	Description of Strata.	Thick- ness of Strata. Ft. In.	Depth from Surface. Ft. In.	No.	Description of Strata.	Thick- ness of Strata. Ft. In.	Depth from Surface. Ft. In.
1	Red measures (Trias and Permian) ...	251 0	251 0	14	Strata ...	41 4	692 6
2	Strata (Coal-measures) ...	209 2	460 2	<i>Eureka Coal-seam—</i>			
<i>Main Coal-seam—</i>				15	COAL (usually 3 ft. 9 ins. to 4 ft.)	2 8	695 2
3	COAL (usually 13 to 16 feet) ...	5 0	465 2	16	Strata ...	56 7	751 9
4	Strata ...	28 0	493 2	17	COAL ...	1 11	753 8
5	COAL ...	2 0	495 2	18	Strata ...	31 9	785 5
6	Strata ...	58 5	553 7	19	COAL ...	1 0	786 5
				20	Strata ...	25 6	811 11
				21	COAL ...	2 1	814 0
				22	Strata ...	23 2	837 2
				23	COAL ...	0 3	837 5
7	COAL ...	1 5		24	Strata (bottom of shaft) ...	50 6	887 11
8	Stone ...	0 8		25	Strata (bore-hole)	104 9	992 8
9	COAL ...	1 5		26	COAL ...	3 9	996 5
				27	Strata ...	97 6	1,093 11
10	Strata ...	52 6	609 7	28	Grey, brown, and red sandstone ...	25 0	1,118 11
<i>Woodfield Coal-seam—</i>				29	Very hard stone ...	4 1	1,123 0
11	COAL ...	5 1	614 8				
12	Strata ...	28 3	642 11				
<i>Stockings Coal-seam—</i>							
13	COAL ...	8 3	651 2				

APPENDIX B.—No. 1 BORE-HOLE.

No.	Description of Strata.	Thick- ness of Strata. Ft. In.	Depth from Surface. Ft. In.	No.	Description of Strata.	Thick- ness of Strata. Ft. In.	Depth from Surface. Ft. In.
1	Red measures, C 195 ft. ...	263 6	263 6	9	COAL, A ...	5 1½	376 7½
2	Strata ...	36 2	299 8	10	Strata ...	41 10½	418 6
3	COAL ...	1 10	301 6	11	COAL, B ...	3 1	421 7
4	Strata ...	5 0	306 6	12	Strata ...	172 11	594 6
5	COAL ...	0 5	306 11	13	COAL ...	1 0	595 6
6	Strata ...	44 7	351 6	14	Strata ...	76 0	671 6
7	COAL ...	1 0	352 6	15	COAL ...	0 10	672 4
8	Strata ...	19 0	371 6	16	Strata ...	105 2	777 6
				17	Red and grey grit	19 0	796 6

APPENDIX C.—No. 2 BORE-HOLE.

No.	Description of Strata.	Thick- ness of Strata. Ft. In.	Depth from Surface. Ft. In.	No.	Description of Strata.	Thick- ness of Strata. Ft. In.	Depth from Surface. Ft. In.
1	Red measures, C 195 ft. ...	282 0	282 0	7	COAL, A ...	5 5	382 7
2	Strata ...	3 6	285 6	8	Strata ...	38 5	401 0
3	COAL ...	1 3	286 9	9	COAL, B ...	3 3	404 3
4	Strata ...	43 6	330 3	10	Strata ...	237 0	641 3
5	COAL ...	0 9	331 0	11	COAL ...	0 9	642 0
6	Strata ...	26 2	357 2	12	Strata ...	113 0	755 0
				13	Hard grey rock	1 4	756 4

Mr. C. FOX-STRANGWAYS read the following "Notes on the Stratigraphy of the Newer Rocks of the Netherseal Borings":—

NOTES ON THE STRATIGRAPHY OF THE NEWER ROCKS
OF THE NETHERSEAL BORINGS.

By C. FOX-STRANGWAYS, F.G.S.

The Netherseal borings were sunk in the valley about $\frac{1}{2}$ mile north of the village of Netherseal, where the pebble-beds of the Bunter Sandstone crop out, and, with the exception of the valley-deposits, commence at once in this formation.

As the strata passed through in the two borings were practically the same, a description of one of them answers for both. They were taken to a depth of 756 and 796 feet respectively, and after passing through 262 feet of Triassic and Permian rocks, entered the Coal-measures.

The Trias and Permian rocks consist of alternations of sandstones and pebble-beds, the included fragments in the latter becoming slightly more angular as their base is approached. The base, reached between 262 and 263 feet, is a fairly sharp line; and the change from red Permian marls and breccias to grey sandstone and shales with Coal-measure plants is very distinct. It is, however, not nearly so easy to fix the upper limit of the Permian or to separate it from the overlying Bunter.

The latter, which is a conglomerate of well-rounded pebbles, passes down into beds that contain, in the upper part, a few angular fragments; but lower down these angular fragments become far more numerous, and the beds gradually pass into purple subangular breccias exactly similar to the Permian of this district.

When we consider the conditions under which the Bunter and Permian were probably laid down in this district, it is clear that the junction between them might in many cases be very irregular, and their respective strata would become somewhat mingled. It is tolerably clear that the Permian breccias of this district were formed along the margin of the old Permian lake or inland sea which lay to the westward, and were the result of subaërial denudation along what was probably a very irregular coast-line: the angular detritus being chiefly deposited in the depressions where the valleys of this old land entered this lake.

At the close of the Permian period, these tranquil conditions gave place to the inrush of waters which produced the well-rounded pebbles of the Bunter, and the two would naturally become mingled along what was still the shore-line of both these deposits. In fact there is no reason why, in some cases, the subaërial detritus of the Permian should not be superimposed on the subaqueous deposits of the Bunter: at any rate, in this district which was the eastern boundary of both these formations.

From an examination of the cores from this boring, it is seen that the lower portion of the Red Measures is almost wholly composed of angular detritus, with a few thin intercalated beds of variegated marl and coarse friable sandstone containing some angular fragments. These measures continue upwards for about 80 feet, when they are succeeded by coarse red sandstones with large rounded pebbles, and although there are still a few angular fragments these become considerably less numerous, and the rock attains a decided Bunter aspect. Above this, there are many alternations of sandstones and pebble-beds, and, although there is still a certain amount of angular fragments, the rock may be considered a fairly well rounded conglomerate, and there is no reason why it should not be classed with the Bunter pebble-beds of this area.

Prof. Hull has classed the whole of the Red Measures in this section with the Bunter Sandstone, while others are of opinion that nearly all the beds are of Permian age.

It is, however, much more probable that a large part of these beds represents a passage from one formation into the other, and that there was here, along the margin of these deposits, an oscillation of the physical conditions under which they were respectively laid down. If this be the case, it is useless to attempt to fix any exact division between the two, and all one can say is that the last 80 feet, more or less, of the Red Measures corresponds most nearly with the Permian beds as seen at the outcrop. This is rather more than the normal thickness when exposed at the surface, or where met with in shallow bore-holes; but we should expect the beds to thicken somewhat in this direction, although it is not probable that the breccias themselves ever become much thicker than this.

Mr. W. W. WATTS read the following "Notes on Some Rock-specimens from the Borings at Netherseal":—

NOTE ON SOME ROCK-SPECIMENS FROM THE BORINGS AT NETHERSEAL.*

By W. W. WATTS, M.A., F.G.S.

The following specimens were submitted to the writer by Mr. Binns for examination :—

- | |
|--|
| 1.—No. 1 Boring, Netherseal, depth 262 feet. |
| 2.— " " " 795 feet. |
| 3.— " " " 796 feet, bottom of bore-hole. |

* Communicated by permission of the Director-General of the Geological Survey.

- 4.—No. 2 Boring, Netherseal, depth above 699 feet.
 5.— „ „ „ 699 feet. (E.2771)
 6.— „ „ „ 732 feet. (E.2772)
 7.— „ „ „ bottom of bore-hole. (E.2773)

(1) This specimen is a consolidated, non-calcareous marl, mottled greenish-grey and red; it is slightly slickensided and unctuous. It is like the marls which occur in the Permian and Triassic rocks.

(2) The second specimen is a pale lavender-coloured, slightly mottled, micaceous sandstone of a type not uncommon in the New Red Sandstone and Carboniferous systems.

(3) The third is a similar stone with brown staining in large and small spots. These sandstones are slightly calcareous, no fossils or pebbles occur in them, and the writer is not able to note any distinctive features about them. They were not sliced for microscopic examination.

(4) This is a fine-grained, white, micaceous, felspathic sandstone, loose in texture and not calcareous. It might be a Coal-measure sandstone.

(5, 6, and 7) The other three specimens have been sliced and examined microscopically. Those from the depths of 699 and 732 feet are alike, and have the general appearance of dolomites, or rather of sandy rocks cemented by dolomite. They effervesce with acid, and it is then easy to see the sand-grains embedded in a buff dolomitic matrix. The specimen from the bottom of the bore-hole has, however, a different appearance; it is hard, crystalline-looking, of a purplish hue, and certainly looks very much like a quartzite of the Nuneaton type. But under the microscope, it is not to be distinguished from the two preceding rocks. It consists of angular chips of minerals of which quartz is the chief, but feldspars, iron-ores, ferro-magnesian minerals, a very little mica, and a few grains of such dense minerals as rutile and zircon, also occur. All these minerals are embedded in a cement of crystalline dolomite.

It is needless to say that this description does not correspond to that of a quartzite, and certainly not to that of the Nuneaton quartzite, which consists of rounded grains of quartz embedded in silica which has grown in crystalline continuity with that of the original grains.

The fact that the rock has a dolomitic cement does not, of course, by itself prove that it is not of pre-Carboniferous age, for there is no reason why dolomite should not be found in Cambrian or pre-Cambrian rocks, but none has hitherto been found in this area. On the other hand, it is well known that the Carboniferous Limestone of Bredon and Grace Dieu, near Charnwood Forest, is a dolomite, and this is the rock which would

be in its proper sequence in the Netherseal boring. Microscopic slides of these Leicestershire rocks which have been prepared do not present identical features with the Netherseal rock; they are less sandy, especially that from Bredon, while that from Grace Dieu has very fine gritty particles in it, but these particles are much smaller than those of the rock under discussion. This is not a point of great importance, for if the shore-line of the Carboniferous Limestone sea was nearer to Netherseal than to Grace Dieu we might expect to find more and larger grit-grains in the rock from the former place.

Prof. E. HULL (London) thought that these papers were extremely interesting from the fact that they dealt with three, if not four, successive formations. First, they had to deal with the New Red Sandstone; possibly Permian; then Coal-measures; and finally the underlying rocks. As regards Mr. Fox-Strangways' remarks, there was nothing to which he (Prof. Hull) could take exception, and he quite concurred in the view that there might be a little mingling between the Permian and the Coal-measures. When he (Prof. Hull) was examining the cores at Netherseal colliery, it did not appear to him that there were any Permian beds. Coming to the Coal-measures and the remarkable faults that Mr. Binns had described, there were few collieries where the managers had to deal with more difficulties from faults, etc., than at Netherseal. Then the question arose, what were the rocks at the bottom of the Coal-measures. When he was examining the cores, he was struck by the fact that they instantly left strata containing carbonaceous matter, plant-remains, shale, and sandstone, every one of them full of plant-remains, and went into beds in which there was no trace of animal or plant fossils. There were two borings; in No. 1, which he saw, the cores were very peculiar—principally purplish variegated grits and shales (specimen exhibited); this rock might be found either in Cambrian or Silurian. Another rock (exhibited) might be found in other formations, but in dealing with a question of this kind they must have regard to the physical conditions of the district, and they knew for other reasons that the Leicestershire coal-field was deposited very near the margin of the ancient lands of the Carboniferous period—the great band of old rocks which stretches across the centre of England. No doubt the Leicestershire coal-field was formed in near proximity to that old central barrier of ancient rocks. Therefore, in trying to determine the age of these rocks, they must keep that fact in mind. But in No. 2 boring, of which specimens were on

the table, they found unmistakable Warwickshire quartzite. Mr. Binns sent him some larger specimens, and on seeing them he had no hesitation whatever in pronouncing them to be quartzite. He also took the precaution, before he replied to Mr. Binns' question regarding their age, of sending them to Prof. Lapworth, who wrote back that he entirely concurred in his (Prof. Hull) view, and that he believed they were some Cambrian quartzites. Mr. Watts, for whose opinion he had some respect, had examined these rocks, and thought he had discovered dolomite. All he must say was that, if those specimens were dolomite, he had never seen a dolomite in his life. A true dolomite is a magnesian carbonate of lime; and it was quite true that north of this district they had magnesian dolomite. Bredon Hill was a Carboniferous Limestone deposit, formed originally in the open sea, principally by organic agency. Mr. Watts says that, at depths of 699 and 732 feet, this rock has the general appearance "of dolomites, or rather of sandy rocks cemented by dolomite." That might be, but it by no means made it a dolomite, because it was a sandy rock cemented by carbonate of lime and magnesia. Then Mr. Watts gave the composition of it under the microscope as "angular chips of minerals of which quartz is the chief, but felspara, iron-ores, ferro-magnesian minerals, a very little mica, and a few grains of such dense minerals as rutile and zircon also occur." He (Prof. Hull) believed that the whole of these rocks were very ancient, probably of Cambrian age, and the statement that it was a dolomite belonging to the Carboniferous Limestone in direct succession under the Coal-measures, did not hold good, because there were no representatives of the Millstone Grit or Yoredale beds. He did not see any reason for departing from the opinion which he originally expressed, that these were representative of very ancient Cambrian rocks that formed a margin of the Leicestershire coal-field to the south and extending doubtless under the eastern and central parts of England almost to the Wash of Lincolnshire.

Mr. M. H. MILLS said that the members owed a great deal to Mr. Binns for bringing the matter before them and publishing the details of the boreholes. Mr. Binns was a geologist as well as a mining engineer, and that was of great advantage to him in the peculiar difficulties with which he had to deal at Netherseal. Mr. Watts had considerable experience in that district, and Prof. Hull also had an extensive knowledge of those particular rocks and had probably seen more of them than any other man. Only recently, he had put down a deep borehole at Ruddington, and he found the greatest difficulty in ascertaining where they were. The borehole passed through Coal-measures into what looked like

Millstone Grit, and no more boring was done after Mr. Watts decided that it was Millstone Grit. It was a pity that borehole was stopped, but it could not be expected that private individuals would carry on explorations which were to a great extent scientific; it seemed a pity that government did not do something to assist in those deeper explorations, because the boring once stopped could not well be opened out again.

At the end of Mr. Binns' notes, he suggested that the main coal-seam was the same as the Kilburn coal-seam in Nottinghamshire. He would like to ask whether Mr. Binns had gone at all into the question of the correlation of the coal-seams with those of Nottinghamshire, as personally he felt doubtful about the identity of the two seams.

Prof. HULL said that it would be difficult to establish an identity between the coal-seams in the Leicestershire coal-field and those of Nottinghamshire, from the very fact that it was almost impossible to establish an identity between the eastern and western districts of the Leicestershire coal-field itself.

Mr. C. FOX-STRANGWAYS (London) said that the effect produced on the outcrop of the rocks by the fault is very marked at Gunby Lea, where owing to the hade it reaches the surface at about 480 feet south of its position in the workings. The great spread of pebble-beds which stretches across the country from Netherseal northwards is here sharply cut off and directly succeeded by the thin sandstones and marls at the top of the Lower Keuper. The line of fault nearly coincides with the road, and has a somewhat curious effect on the water-bearing capacity of the rocks at this spot. A well 29 feet deep on the northern side of the road is full of water to the top, while another well which had lately been sunk exactly opposite and not more than 45 feet distant, to a depth of 40 feet, is perfectly dry, showing that the water is completely dammed up by this fault on its northern side.

Until the lower seams of coal have been more extensively explored, it is difficult to correlate those at Netherseal with the nearest section we have—namely, that of the Hastings and Grey shaft at Moira colliery; but, on the whole, the intervals between the several seams agree sufficiently well for us to suppose that the lower measures at the two places are identical. At Netherseal pit, there are about 300 feet of measures with five coal-seams between the eureka and the lowest coal-seam; while at Moira colliery there are about 380 feet of measures also with five seams between the eureka and the so-called Kilburn coal-seam. It is a curious fact, however, that neither of these sections agrees in the least with the

measures proved in the boreholes. He was led, therefore, to the supposition that these must be near the limit of the coal-field, and that the lower portion of the Coal-measures thin out very rapidly in this direction.

Mr. G. J. BINNS thanked the members for the reception accorded to his paper, which was due entirely to the fact that two gentlemen, eminent in their profession, had been good enough to throw light on a subject otherwise of little interest. He was under the impression, when it was first struck, that the rock at 777 feet in No. 1 bore-hole was Millstone Grit, and for that reason he considered it inadvisable to go on with the boring: it appeared that his opinion was incorrect. Mr. Watts thought that they should have carried the borehole further; but it was rather an expensive matter carrying on a borehole at a depth of 800 feet. If it had not been for Mr. Fox-Strangways' remarks on the surface-evidence of the Gunby fault, he would have thought that it was of pre-Permian age. He could not check Mr. Fox-Strangways' evidence; but he should otherwise have been under the impression that the fault was pre-Permian, and that the decrease in the thickness of the Coal-measures between the Netherseal colliery shaft and the bore-holes was due to denudation, which took place between the upheaval of the Coal-measures and the deposition of the Triassic rocks.

Mr. W. W. WATTS said that was not the place to discuss whether the disputed rock should be called a quartzite, dolomite, or sandy rock cemented by dolomite. The Nuneaton quartzite was known not to be cemented by dolomite; and if it were, it would not conform to the definition of quartzite. Anybody who was familiar with dolomites knew two facts about them: in the first place, that they had a knack of looking much like quartzite; and another thing was, that the amount of gritty material present in dolomites varied very much indeed from point to point. He had no doubt that Prof. Hull knew the "dolomites" of Ireland well; they occupied a strip over a very large area bordering the Carboniferous Limestone, and where it came into contact with the older rocks it frequently passes along the margin into dolomite. This was the class of rock which the specimen much resembled.

The PRESIDENT moved a vote of thanks to Messrs. Binns, Fox-Strangways and Watts for their interesting papers, and the motion was agreed to.

The following paper by Mr. C. E. Hawkins on the "Occurrence of Iron Ores and Iron Manufacture in the Weald" was read:—

OCCURRENCE OF IRON ORES AND IRON MANUFACTURE IN THE WEALD.*

By C. E. HAWKINS.

The author regretted that owing to pressure of business he was unable to enter into the question of the occurrence of iron-ores in the Weald as fully as he had intended. At present he would be able to give only an outline of the subject, though he hoped to lay fuller information before the members on another occasion.

The Weald is the tract of country lying between the Chalk hills known as the North and South Downs, and extending from Selborne and Petersfield on the west to Romney Marsh on the east, a distance of about 80 miles. The greatest width of the Wealden area is about 35 miles, as measured in a north-and-south direction from Maidstone to Eastbourne.

The highest formation in the Wealden area is the Upper Greensand which underlies the Chalk throughout the district, except through a part of Kent. The beds are sandy and calcareous, and they do not contain any ironstone.

The next lowest formation is the Gault, running all round the Weald from Folkestone to Eastbourne. It consists almost entirely of clay.

Below the Gault comes the Lower Greensand with the Atherfield Clay at its base. The Lower Greensand is subdivided by geologists into:—

- (1.) Folkestone Beds.
- (2.) Sandgate Beds.
- (3.) Hythe Beds.
- (4.) Atherfield Clay.

The Folkestone Beds often contain iron-sandstone locally called "carstone;" iron-sandstone is also found occasionally in the Hythe Beds. The Sandgate Beds sometimes contain a ferruginous grit which the late Mr. F. Drew thought might be of some value as an iron-ore.

Beneath the Lower Greensand comes the Weald Clay, a freshwater formation, the strata previously described having a marine origin. The Weald Clay consists principally of clays and shales, with occasional bands of shelly limestone; sand and sandstone are sometimes met with; nodular clay-ironstone also occurs.

*The writer is indebted to various papers by Mr. Mark Antony Lower, originally published in the *Sussex Archaeological Collections*, for many of the details relating to the Wealden iron-works.

The next formation, likewise of freshwater origin, consists of a series of sands and clays known as the Hastings Beds, which may be divided broadly into :—

- (1.) Tunbridge Wells Sand.
- (2.) Wadhurst Clay.
- (3.) Ashdown Sand (with Fairlight Clays).

The Tunbridge Wells Sand consists of alternations of sand and sandstone with loamy and clayey beds. The sandstone is sometimes ferruginous. These beds are very variable, and they do not appear to contain any iron ore.

The Wadhurst Clay consists of beds of clay, shale, and sandstone ; it also contains clay-ironstone, in layers rarely exceeding 4 or 5 inches in thickness and in small nodules.

The Ashdown Sand consists of alternations of sand and sandstone, clay and shale, with clay-ironstone in the upper beds. "At Snape Wood there are several beds of clay-ironstone in the sands, which have been worked for ore since the railway was made ; one bed varies from 6 to 8 inches in thickness, another 12 inches ; the third is less constant, but sometimes attains a thickness of 18 inches." *

North-east of Battle, there are a few exposures of a lower set of beds, viz., the Purbecks, but these consist of shales and limestones, and they do not furnish any iron ore.

The Hastings Beds extend from Horsham to Romney Marsh, and occupy an area measuring some 48 miles long and 20 miles wide. It was principally over this area that the ironworks were scattered, obtaining ore from the Wadhurst Clay, and, to a lesser extent, from the Ashdown Sand. There were, however, a few ironworks distributed over the areas of the Weald Clay and Lower Greensand, and the sites, both of the furnaces and of the forges can still be identified by the occurrence of slags. Most of these are so far removed from the Hastings Beds that they must have derived the supply of ore from some other source. The clay-ironstone from the Weald Clay would doubtless have been used, and perhaps the carstone from the Lower Greensand was smelted in those furnaces which were situated at the western extremity of the Wealden area.

The manufacture of iron in the Weald dates back at least to the time of the Roman occupation of this country. Roman remains, including pottery and coins of the time of Vespasian, have been found in the cinder-heaps.

* *Geology of the Weald*, page 72, by the late Mr. W. Topley.

The earliest mention of the iron trade is made in a document of Henry III., dated 1266, granting tolls on loads of iron to the town of Lewes.

A cast-iron slab in Burwash church affords perhaps the oldest specimen known of the iron manufacture of the fourteenth century. The writer has seen many cast-iron sepulchral slabs over graves in the Wealden churchyards of Kent and Surrey, and also many fire-backs, but none of very early date. Specimens of andirons or fire-dogs may be found ranging from the end of the fifteenth to the end of the seventeenth century. The railings round St. Paul's cathedral furnish the best existing example of Wealden iron; they were partly removed in 1874, but their original weight, including the gates, was above 200 tons. They cost £11,202 0s. 6d., and were made at Lamberhurst.

Banded guns of wrought iron in the Tower of London and elsewhere are supposed to be of Sussex manufacture. A mortar found at Eridge Green, Frant, is said to have been the first made in England. The first cannons cast in England were made at Buxted, in Sussex, in 1543.

In the beginning of the sixteenth century, the iron trade was in a flourishing condition, and so continued throughout the seventeenth century. Even as late as 1724, the iron trade was the chief interest of the county of Sussex. In the seventeenth century, steel was made at several places, particularly at Warbleton and Robertsbridge. In 1610, there were about 140 hammers and furnaces for iron in Sussex.

A writer in the *Pick and Gad** quotes the following passage from Camden's *Britannia* :—

It [i.e., the county of Sussex] is full of iron-mines everywhere, for the casting of which there are furnaces up and down that country, and abundance of wood is yearly spent; many streams are drawn into one channel, and a great deal of meadow-land is turned into ponds and pools for the driving of mills by the flashes; while beating with hammers upon the iron fill the neighbourhood round about night and day with their noise . . . The proprietors of the mines by casting of cannon and shot get a great deal of money.

The same writer remarks as follows with reference to the ore :—

The stone from which this iron was manufactured seems principally to have been a spathose ore, or an altered spathose ore, where the carbonate of iron has been converted into a hydrated peroxide. The percentage of this class of ore seems to be very good, some which I have tried producing as much as 50 per cent.; a fair average would seem to range from 25 per cent. to 40 per cent. Other classes of ores have also probably been used, for clay-ironstone is often found, although, as far as I personally observed, generally poor, and siliceous ores occur in other places. But the spathose ore is certainly the most valuable—indeed, as far as I can judge, it seems the only stone existing in sufficiently compact bodies to be worked to profit.

* No. 2, page 57.

In consequence of the falling off in the supply of charcoal, the iron trade greatly diminished in the first half of the eighteenth century, so that the amount of iron made, which had formerly reached 180,000 tons per annum, was in 1740 reduced to rather less than one-tenth of that quantity. At that date there were 10 furnaces in Sussex. In 1788, there were only 2 furnaces in Sussex, and in 1796, there was only 1 furnace, viz., at Asburnham, making 173 tons of iron in the year, and this lasted till 1825 or 1828.

The enormous consumption of wood rendered the production of iron more expensive than in those localities where the coal and iron-ore are found in close proximity to each other, and the gradual failure of fuel led to the final extinction of the Wealden iron trade.

The PRESIDENT moved a vote of thanks to Mr. Hawkins for his notes on an interesting industry, and the motion was agreed to.

The following paper by Mr. A. H. Halder on "Mining in Rhodesia," was taken as read :—

MINING IN RHODESIA.

By ALBERT H. HALDER.

The writer does not think it necessary to explain the geographical position of Rhodesia, as this country has been more than well advertized of late to the general reader through its political difficulties, therefore he will describe as concisely as possible the geological features, together with its commercial outlook from a mining point of view.

The territory known as Rhodesia, belonging to the British South Africa Company, covers an area of over 750,000 square miles; a country as large as France and Switzerland.

The geological formations generally consist of extensive belts of metamorphic slates, lying between huge granite belts, the latter forming the main bulk of the country. The general bearing is east and west, with little variation, save here and there with a slight dip north.

There are many auriferous areas, some more extensive than others, but they may be averaged from 6 miles in width and 30 to 40 miles in length. The reefs existing are of crystalline nature (hardish quartz) closely resembling the quartz-reefs of Barberton, Murchison, and Leydenburg, they vary in characteristics very considerably, as well as in their respective richness. In most cases these reefs follow the planes of the stratification with great regularity, and are often traceable for many miles with uniform prospects of gold. In some cases gold is visible to the naked eye, while in others good results are obtained by panning.

Gold was found centuries ago, and has evidently been worked to some considerable extent, as there are thousands of ancient workings all over the country. Prospectors chiefly looked for them, instead of searching for virgin reefs. It is generally believed that the ancient miners only worked upon exceedingly rich stuff; there is some truth no doubt in this statement, but the writer noticed old workings from which the prospects were very poor, and in consequence were abandoned at an early stage.

Take, as an example, the Christmas reef, where the line of outcrop of reef can be traced with unusual regularity for some miles, and where the ancient miners sank some 10 different holes with no prospect of success.

These holes are from 10 feet to 15 feet in depth, the reef is of a hungry white colour, giving only colour of gold in the pan. However, some energetic prospectors made up their minds on Christmas Day, 1894, to sink below the ancient workings, and their endeavours were well rewarded, for at a depth of 24 feet a change of the reef took place, a highly auriferous vein was struck 2 feet 6 inches wide, showing marvellous prospects of gold; in fact, the quartz was simply full of nuggety coarse gold. Tip-shafts have been sunk on the line of reef, and in every one rich pay-shoots were discovered. From the writer's own personal inspection, he considers that this reef is one of the richest ever discovered in Rhodesia, and he calculates its regular return to be from 2 to 2½ ounces per ton, although the ancient miners left this bonanza in despair.

Another instance is the Golden quarries in the Sebakwe district, some 160 miles north of Buluwayo, and near the boundary of Mashonaland. In this district are unquestionably rich reefs and large ore-bodies. Many thousands of tons of rock have been shifted by the ancient miners down to a depth of 40 to 60 feet, and the only reason the writer can see for their abandonment, must have been their crude appliances, both for lifting the rock and its treatment. For, judging by the rock at the various dumps, which gives an average return of 15 dwts. per ton, there is no doubt that they were working only the richest of quartz. Indeed, it is surprising to see some 300,000 tons of rock lying ready for milling giving such good returns.

Recent development proves the above statement, as some of the reefs in the Golden quarries and adjoining properties have been proven to a considerable depth, showing excellent results of gold, in fact, many of these reefs are perfectly ready for working.

The reefs in that district are stronger than in other parts of Rhodesia, they vary from 6 to 12 feet wide, and are well embedded in chloritic slate, indicating them to be true fissure-veins.

Some exceedingly promising reefs occur in the Selukwe district, such as the Dunraven, Grace Darling, and others.

The quartz differs much in that district from the quartz found in any of the other fields; its appearance is white, with blue streaks, highly mineralized, carrying a large percentage of galena and pyrites. In the Grace Darling mine, the quartz is very rich in certain shoots, forming simply one mass of specimen, much resembling the famous Thomas reef at Barberton.

Among the other promising fields is the Gwanda field, some 40 miles south-east of Buluwayo. The writer has seen some excellent shows of

gold in some of the developed reefs; such as the Malutti reef, exposing a vein, at a depth of some 60 feet, 3 feet wide, showing visible gold in every fractional piece.

Reverting to the ancient miners, the writer ventures to state his opinion that, in many cases, the cessation of mining operations was due to the incapacity of the miners to cope with difficulties in deep mining, such as increased hardness of rock, influx of water, impoverishing and refractory condition of the ore, etc.

One cannot get away from the fact that in quartz-mining one will experience pinching and making of a vein, and doubtless the ancient miners had no such skill as to follow up a lode which had pinched away.

After a most exhaustive examination, the evidence is most conclusive that the auriferous veins in Rhodesia belong to the class known as true fissure-veins.

There is, however, every indication strongly favouring the view that by future systematic development many rich pay-shoots will be discovered, and it would be an anomaly if upon hundreds of miles of mineralized veins, valuable ore-shoots should not be developed as a result of proper working.

The general conditions for economic mining may be considered favourable. Although there are no streams to utilize for water-power, there is ample water for all other purposes, and fuel and timber in most places are plentiful.

Coal-beds have been discovered south of Buluwayo, and in the neighbourhood of the Zambezi river.

Another great help is the approach of the railway to Buluwayo and Salisbury, thus lessening transport rates and cost of living.

The climate as a whole is exceedingly healthy; the temperature averages 62° to 95° Fahr. The average altitude varies from 4,000 to 5,000 feet above sea-level. There are places where fever prevails, but only in a very light form, and not nearly so deadly as in places like the low country of the Transvaal.

The PRESIDENT moved a vote of thanks to Mr. Halder for his paper, and the motion was agreed to.

[This page may be cancelled in binding the Transactions.]

THE FEDERATED INSTITUTION OF MINING ENGINEERS. SUBJECTS FOR PAPERS.

The Council of The Federated Institution of Mining Engineers invite original communications on the subjects in the following list, together with other questions of interest to mining and metallurgical engineers.

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Assaying.	Mechanical preparation of ores and minerals.
Blowing out of coal and minerals <i>in situ</i> .	Mechanical ventilation of mines, and efficiency of the various classes of ventilators.
Boiler explosions.	Metallurgy of gold, silver, iron, copper, lead, etc.
Bore-holes and prospecting.	Mineral resources of colonies.
Boring against water and gases.	Mining and uses of asbestos, bauxite, etc.
Brickmaking by machinery.	Occurrence of mineral ores, etc.
Brine-pumping.	Ore-sampling machines.
Canals, inland navigation, and the canalization of rivers.	Petroleum-deposits.
Coal-getting by machinery.	Prevention of over-winding.
Coke manufacture.	Pumping machinery.
Colliery explosions.	Pyrometers and their application.
Colliery leases, and limited liability companies.	Quarries and methods of quarrying.
Compressed air as a motive-power.	Rectification of mineral oils.
Consumption of steam and water in engines.	Safety-lamps.
Descriptions of coal-fields.	Salt-mining, etc.
Diamond-mining.	Screening, sorting, and cleaning of coal.
Distillation of oil-shales.	Shipping and discharge of coal-cargoes.
Drift and placer-mining.	Sinking, coffering, and tubbing of shafts.
Duration of coal-fields of the world.	Smelting.
Electric mining lamps.	Spontaneous ignition of coal and coal-seams.
Electricity and its applications in mines.	Submarine coal-mining.
Electro-metallurgy of copper.	Sulphur-mining.
Engine-counters and speed-recorders.	Surface-arrangements of mines.
Explosions in mines.	Surveying.
Explosives used in mines.	Tin-mining.
Faults and veins.	Tunnelling, methods and appliances.
Fuels and fluxes.	Utilization of dust and refuse coal.
Gas producers, and gaseous fuel and illuminants.	Utilization of sulphureous gases resulting from metallurgical processes.
Gas, oil, and petroleum engines.	Ventilation of coal-cargoes.
Geology and mineralogy.	Ventilation of mines.
Haulage in mines.	Water as a motive-power in mines.
Industrial assurance.	Watering coal-dust.
Inspection of mines.	Water-incrustations in boilers, pumps, etc.
Laws of mining and other concessions.	Winding arrangements at mines.
Lead-smelting.	Winning and working of mines at great depths.
Lubrication of trams and tubs.	
Maintenance of canals in mining districts.	
Manufacture of fuel-briquettes.	

MEDALS AND OTHER AWARDS.

SESSION 1889-90.

- "The Economical Working of Steam Boilers at Collieries." By Messrs. William Armstrong, Junior, and W. J. Bird.
 "Improved Coal-screening and Cleaning." By Messrs. T. E. Forster and H. Ayton.
 "Winding, Banking-out, and Screening Plant at East Hetton Colliery." By Mr Simon Tate.
 "Coal-getting by Machinery." By Mr. G. Blake Walker.

SESSION 1890-91.

- "Experiments on Explosives used in Mines." By Mr. M. Walton Brown.
 "Experiments with Carbonite." By Messrs. M. Walton Brown and William Foggin.
 "Notes on the Coal-fields of New South Wales." By Mr. G. Blake Walker.

SESSION 1891-92.

President's Prize (Mr. George Lewis).

- "Mining in New Zealand." By Mr. G. J. Binns.

gold in some of the developed reefs ; such as the Malutti reef, exposing a vein, at a depth of some 60 feet, 3 feet wide, showing visible gold in every fractional piece.

Reverting to the ancient miners, the writer ventures to state his opinion that, in many cases, the cessation of mining operations was due to the incapacity of the miners to cope with difficulties in deep mining, such as increased hardness of rock, influx of water, impoverishing and refractory condition of the ore, etc.

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The PRESIDENT moved a vote of thanks to Mr. Halder for his paper, and the motion was agreed to.

Mr. W. E. GARFORTH read a paper on "Suggested Rules for the Recovery of Coal-mines after Explosions."

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Explosions in mines.	Surveying.
Explosives used in mines.	Tin-mining.
Faults and veins.	Tunnelling, methods and appliances.
Fuels and fluxes.	Utilization of dust and refuse coal.
Gas producers, and gaseous fuel and illuminants.	Utilization of sulphureous gases resulting from metallurgical processes.
Gas, oil, and petroleum engines.	Ventilation of coal-cargoes.
Geology and mineralogy.	Ventilation of mines.
Haulage in mines.	Water as a motive-power in mines.
Industrial assurance.	Watering coal-dust.
Inspection of mines.	Water-incrustations in boilers, pumps, etc.
Laws of mining and other concessions.	Winding arrangements at mines.
Lead-smelting.	Winning and working of mines at great depths.
Lubrication of trams and tubs.	
Maintenance of canals in mining districts.	
Manufacture of fuel-briquettes.	

MEDALS AND OTHER AWARDS.

SESSION 1889-90.

- "The Economical Working of Steam Boilers at Collieries." By Messrs. William Armstrong, Junior, and W. J. Bird.
- "Improved Coal-screening and Cleaning." By Messrs. T. E. Forster and H. Ayton.
- "Winding, Banking-out, and Screening Plant at East Hetton Colliery." By Mr Simon Tate.
- "Coal-getting by Machinery." By Mr. G. Blake Walker.

SESSION 1890-91.

- "Experiments on Explosives used in Mines." By Mr. M. Walton Brown.
- "Experiments with Carbonite." By Messrs. M. Walton Brown and William Foggan.
- "Notes on the Coal-fields of New South Wales." By Mr. G. Blake Walker.

SESSION 1891-92.

President's Prize (Mr. George Lewis).

- "Mining in New Zealand." By Mr. G. J. Binna.

gold in some of the developed reefs; such as the Malutti reef, exposing a vein, at a depth of some 60 feet, 3 feet wide, showing visible gold in every fractional piece.

Reverting to the ancient miners, the writer ventures to state his opinion that, in many cases, the cessation of mining operations was due to the incapacity of the miners to cope with difficulties in deep mining, such as increased hardness of rock, influx of water, impoverishing and refractory condition of the ore, etc.

One cannot get away from the fact that in quartz-mining one will experience pinching and making of a vein, and doubtless the ancient miners had no such skill as to follow up a lode which had pinched away.

After a most exhaustive examination, the evidence is most conclusive that the auriferous veins in Rhodesia belong to the class known as true fissure-veins.

There is, however, every indication strongly favouring the view that by future systematic development many rich pay-shoots will be discovered, and it would be an anomaly if upon hundreds of miles of mineralized veins, valuable ore-shoots should not be developed as a result of proper working.

The general conditions for economic mining may be considered favourable. Although there are no streams to utilize for water-power, there is ample water for all other purposes, and fuel and timber in most places are plentiful.

Coal-beds have been discovered south of Buluwayo, and in the neighbourhood of the Zambezi river.

Another great help is the approach of the railway to Buluwayo and Salisbury, thus lessening transport rates and cost of living.

The climate as a whole is exceedingly healthy; the temperature averages 62° to 95° Fahr. The average altitude varies from 4,000 to 5,000 feet above sea-level. There are places where fever prevails, but only in a very light form, and not nearly so deadly as in places like the low country of the Transvaal.

The PRESIDENT moved a vote of thanks to Mr. Halder for his paper, and the motion was agreed to.

Mr. W. E. GARFORTH read a paper on "Suggested Rules for the Recovery of Coal-mines after Explosions."

Mr. GEORGE MAY moved that the thanks of the members be accorded to The Royal United Service Institution for the use of the rooms, and to the authorities of the Royal Mint, the Home Office Mines Explosives Testing Committee, and the authorities of the Royal Arsenal, for having so kindly opened their works to the inspection of the members.

The motion was agreed to. —

Mr. J. LONGBOTHAM proposed a vote of thanks to the President for his services in the chair.

The motion was agreed to. —

The meeting was then closed. —

The following notes record some of the features of interest seen by visitors to works, etc., which were, by kind permission of the owners, open for inspection during the course of the London meeting on June 3rd, 4th, and 5th, 1897:—

DESCRIPTION OF HOME OFFICE STATION, ROYAL ARSENAL, WOOLWICH, FOR TESTING EXPLOSIVES TO BE USED IN COAL-MINES.

The apparatus (Plate XXVI.) consists of two portions, (1) a horizontal gallery *A* formed of wrought-iron tubing, which is used for the purpose of testing the liability of an explosive to ignite mixtures of coal-gas and air, and (2) a vertical tube *B* to test the effect on coal-dust suspended in air.

The Gas-gallery.—The gas-gallery *A* is fitted at its outer end with an arrangement for fixing a diaphragm *a* of varnished paper, and at the opposite end it is closed by a disc of wrought-iron *b* having an opening in the centre, which is closed by the muzzle of the cannon *C* when the latter is run up into position.

The cannon itself is built strongly of steel and wire, having a bore of a diameter about that of a usual bore-hole. It is mounted on a small trolley running on rails. To prevent accidents in the case of the bursting of the cannon, a concrete wall *D* has been provided on the side on which the observers are situated.

The gallery is fitted on the top with seven safety-valves *c* to remove the strain when the gas explodes; these also serve as sight-holes, by means of which the flame (if any) issues and is observed. Mere observa-

Scale, 6 Feet to 1 inch.

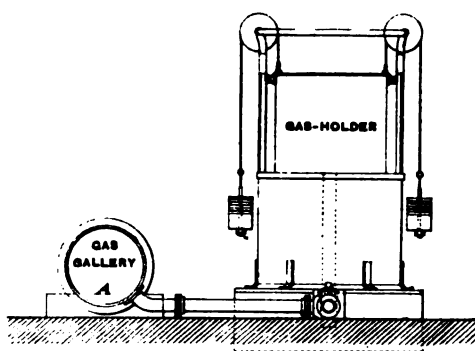
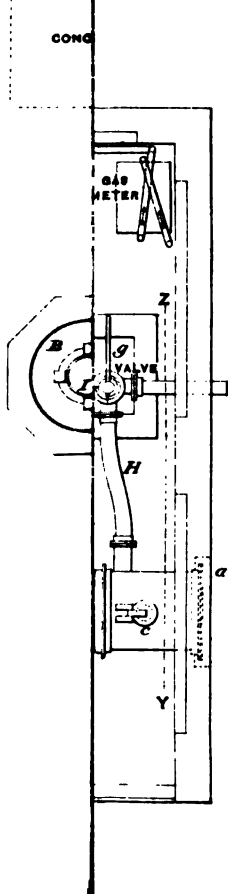
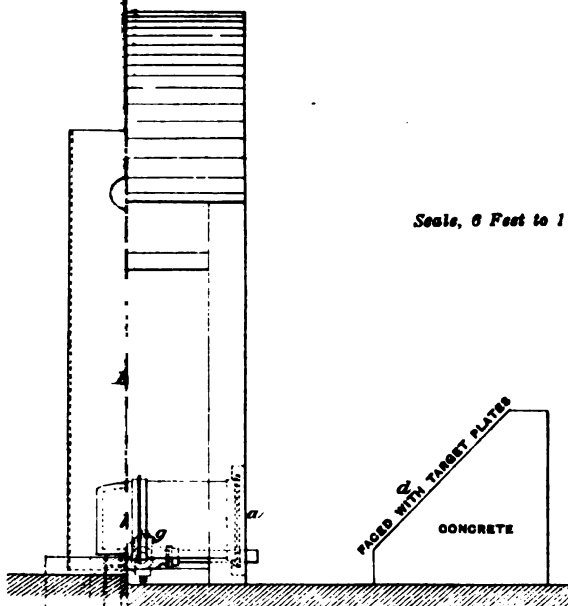
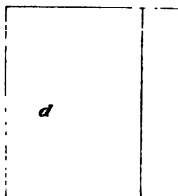


FIG. 3.—SECTION ON LINE Y Z OF FIG. 2.



tion is, however, at best somewhat untrustworthy, and a far more striking test of the ignition or otherwise of the gas is supplied by a tuft of gun-cotton yarn securely fastened in a position *d* at the end of the tube where only an explosion of the gas can ignite it.

Alongside the gallery there is a gasholder *E* fitted with a gauge showing accurately its contents, and also a power-driven centrifugal fan *F*. These are connected by means of pipes *G* and *H* with both ends of the gallery, in such a way that a circulation of air and gas can be maintained through the gallery, gas-holder, and fan.

In preparing to fire a charge in this portion of the apparatus, the cannon *C* is loaded and run up to the gas-gallery *A*, the gas-holder *E* filled with a measured quantity of gas at atmospheric pressure, and then, by opening the valves *e*, *f*, and *g* with which the connecting-pipes *G* and *H* are fitted and starting the fan *F*, this gas is driven into the gallery, air being at the same time removed from the opposite end. By keeping up this circulation for about 1 minute a uniform mixture of gas and air is obtained with very little leakage. The valves are then closed, the gas-holder emptied, and the charge fired, the results being ascertained in the manner indicated above.

The Coal-dust Apparatus.—The coal-dust apparatus consists of a vertical tube *B* resting on a bed of concrete, in the centre of which another cannon *I* is placed vertically, being fixed in position by slats of wood. The tube is fitted, near its base, with an opening in the side, closed by a strong door *h*, through which the loading of the cannon is effected, and also, near the top, with an air and observation hole *i*. Into this tube, coal-dust is blown by a fan *K* similar to the one above referred to, the dust being fed into the pipe by means of a hopper *L*, as shown in the drawings.

In operating this portion of the apparatus, air is driven along the pipe past the hopper, from which it carries with it the necessary supply of coal-dust; and as soon as the operator considers that sufficient coal-dust has been blown into the vertical tube the charge is fired.

The testing station consists of two buildings, one of which contains the gas-gallery, etc., as described, and has one side completely open. A second building on this side is fitted with an observation-slit for the use of those attending the experiments. This building is also used as an office and store.

It must be clearly understood that the apparatus is experimental only, and experience may show the necessity of more or less modification.

ROYAL MINT, LONDON.

Gold bullion is received from the Bank of England, in the form of ingots, 8 inches long, 3 inches wide and 1 inch thick. The bullion is assayed on receipt, and together with the weight of base metal forming the alloy (copper), is melted in crucibles, made of a mixture of plumbago and fire-clay, each containing 1,200 ounces. The melting-room contains two rows of coke-furnaces, in which the crucibles are placed. When the metal is melted, the crucible is raised by means of a crane, and placed on a cradle. The molten metal is stirred with an iron



FIG. 1.—MELTING-ROOM, RUNNING SILVER INTO MOULDS.

rod, and the crucible being slowly tilted, the metal runs into a series of vertical well-oiled iron ingot-moulds, which move transversely underneath on a carriage, as shown in Fig. 1. The bars, weighing about 150 ounces, are 21 inches long, and vary in width and thickness for manufacture into sovereigns or half-sovereigns. The ingots, if found on trial to be of standard fineness, are then sent into the rolling-room. Standard gold contains 11 parts of pure gold and 1 part of alloy (copper), the fineness being $916\frac{2}{3}$.

Silver bullion is bought in the open market, at the price of the day. The ingots, about 18 inches long, 5 inches wide and 4 inches thick,

weighing about 1,000 ounces, when assayed, are melted together with the proper weight of alloy (copper) in crucibles, each containing about 5,000 ounces. After the metal is melted, it is poured into well-oiled moulds. The bars for shillings are 22 inches long, 2 inches wide and $\frac{3}{8}$ inch thick, and are tested for fineness before being sent into the rolling-room. Sterling silver contains 37 parts of pure silver and 3 parts of alloy (copper), the fineness being 925.

In the rolling-room, the ingots are reduced in thickness, by repeated passing through a rolling-mill, whose rolls are gradually brought nearer and nearer together (Fig. 2). The strips or fillets are at first reduced

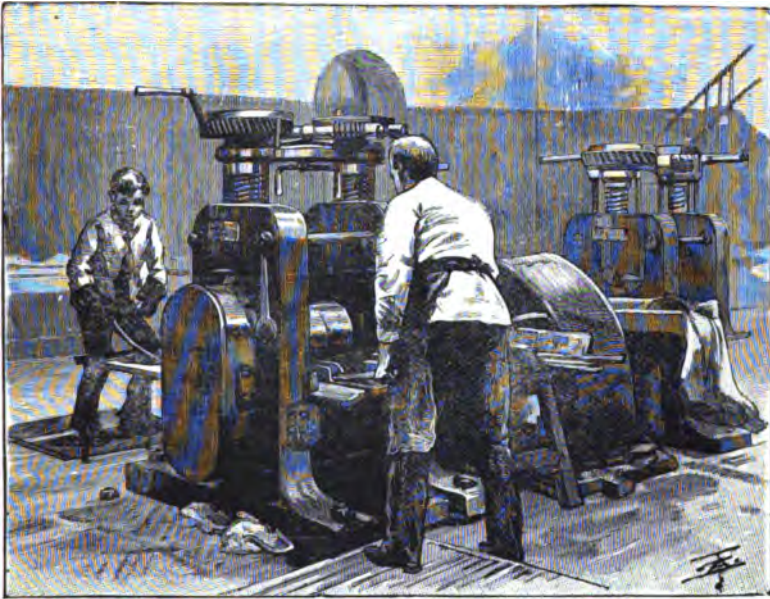


FIG. 2.—ROLLING-ROOM, ROLLING INGOTS INTO STRIPS OR FILLETS.

$\frac{1}{8}$ th inch in each rolling, but finally only $\frac{1}{100}$ inch. The metal becomes hard and brittle in rolling, and it is annealed and rolled until the fillet attains the required thickness. The strips or fillets from which gold coins are made must be within $\frac{1}{10000}$ inch of the required thickness, as a margin of 0.2 grain per sovereign means a difference of £1,600 in 1,000,000 sovereigns.

The reduction of a silver ingot to the fillet form is accomplished in the same way as with gold.

Bronze (95 parts of copper, 4 parts of tin, and 1 of zinc) is bought in strips or fillets for coinage.

The strips or fillets are taken to the cutting-room, where they are rapidly cut up into circular discs or blanks (Fig. 3). The fillet passes below two punches and over two holes, and two gold and silver blanks are formed at a time, save in the case of large silver coins. Five copper blanks are cut at a time; the blanks fall through a tube into a tray at the rate of 400 per hour.

In cutting the blanks out of the fillet, much metal is wasted, and this *scissel* is thrown into the crucible and re-melted into ingots. The scissel is about equal in weight to the blanks.



FIG. 3.—CUTTING-ROOM, CUTTING-MACHINE MAKING BLANKS.

In the same room is the marking-machine, which raises the edge formed upon all coins for the protection of the face. The blanks are run into a groove formed on a rapidly revolving disc, and the edges are raised at the rate of 600 per minute (Fig. 4).

The soundness of silver coins is tested by the ringing process, in which the coins are thrown with rapidity upon a flat stone slab, and any coin yielding a dull sound is picked out and sent to the melting pot.

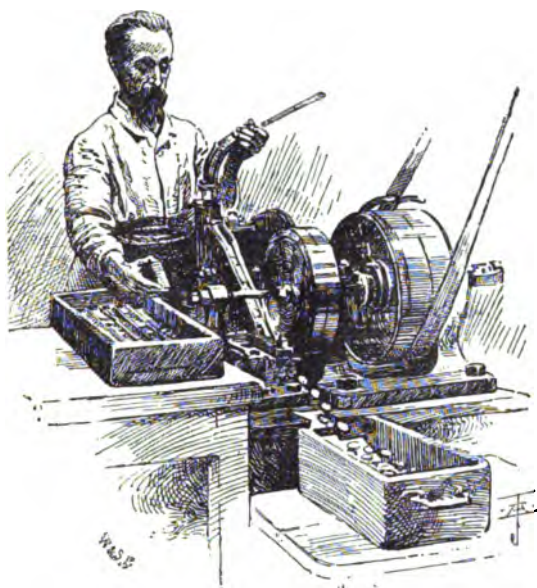


FIG. 4.—CUTTING-ROOM, MARKING-MACHINE RAISING EDGES ON BLANKS.



FIG. 5.—ANNEALING FURNACE.

The blanks are brought in bags to the annealing-room, in which there are several furnaces. The blanks are placed on iron trays, and heated in an oblong oven (Fig. 5). When sufficiently heated, the trays are withdrawn, the blanks tipped into perforated copper basins, and carried into an adjacent room. The blanks are then dipped into a water-tank, next into dilute sulphuric acid, and afterwards rinsed with water; the blanks are dried by being placed in a revolving-box containing beech sawdust (Fig. 6). After a few revolutions, the blanks are emptied into a sieve, and the sawdust shaken out. The blanks



FIG. 6.—DRYING BLANKS.

are greatly improved in appearance by this treatment, which renders them bright and lustrous. Bronze coins are specially treated to give them a dark colour, and so prevent them from being mistaken for gold coins. The sawdust is used again, after being dried on a hot slab.

In the die and medal-rooms, dies may be seen in every stage of progress. The collection of medals contains many samples of beautiful workmanship, and the coins are specimens of the work of the Royal Mint for many years. A punch, in relief as in the actual coin, is produced from a die, which is engraved by tedious labour, with sharp

and hard tools, on a piece of softened steel. The punch, being hardened, is forced by pressure into a piece of softened steel, which after careful hardening, is used as a die or counter-die. By careful attention, one punch can make a large number of dies.

The blanks and the dies are the main elements of the actual process of coinage. The counter-die is placed face upwards in a frame on the bed, and the die is fixed face downwards to the moving arm of the coining press (Fig. 7). The blanks are fed singly on to the counter-die, the die is brought down by the action of a lever, and the force impresses the devices

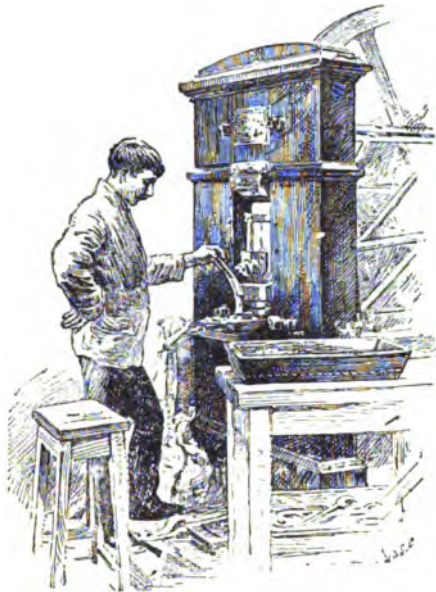


FIG. 7.—COINING PRESS.

upon the blank, which is confined within a steel collar, with a plain or milled or lettered edge in certain cases, so as to prevent lateral flow of the metal. The blanks are fed into the press, from a tube or hopper, from which they are pushed laterally by means of a sliding-plate, so as to place them in the collar and on to the counter-die, and slides them off when coined.

Gold and silver coins then pass into the weighing-room, where they are passed into an automatic weighing-machine. The coins are fed into a tube, from which they fall one by one into a balance-pan. If of proper weight, each coin is thrown into one compartment; if overweight into a

second, and if under weight, into a third (Fig. 8). In addition, gold and silver coins are weighed both in small and large parcels, in balances that turn with 1 grain, with weights of 1,200 ounces (Fig. 8). Bronze coins are only weighed in bulk.

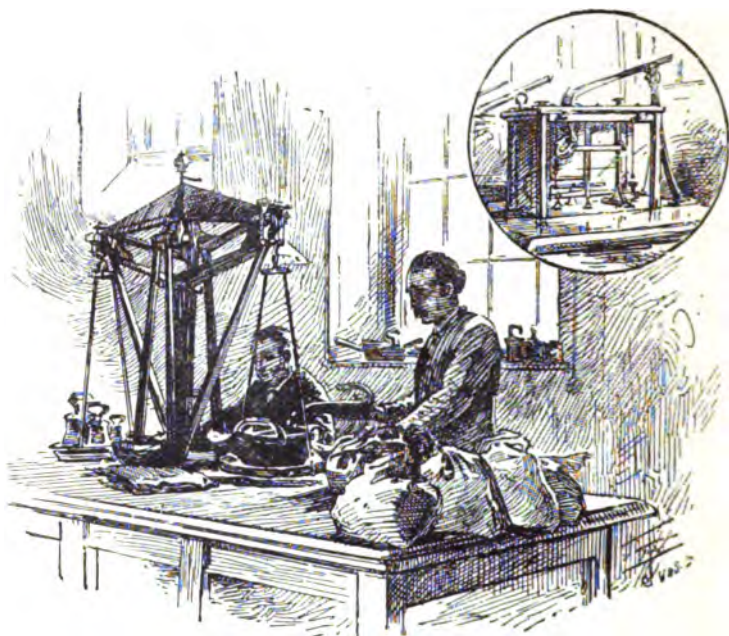


FIG. 8.—WEIGHING-ROOM.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND
MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT,
JULY 12TH, 1897.

MR. E. B. WAIN IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

Mr. J. D. BAILIE read the following paper on "The Steam-Turbine Engine," etc:—

THE STEAM-TURBINE ENGINE AND ITS APPLICATIONS
TO MINING INDUSTRY.

By JNO. D. BAILIE.

In the ordinary or reciprocating engine at the end of each stroke, *i.e.*, twice during each revolution, the direction of the motion of the piston, etc., is completely reversed, and at the instant of reversal there is necessarily a momentary absolute stoppage of the travel of the piston: this means that, with an engine the crank-shaft of which makes 100 revolutions per minute, there are 200 stoppings and re-startings of the essential part of the engine, in fact one might say of the engine itself—for the cylinder and piston may be considered as such, the various accessories being simply distributing and regulating devices—in the same period of time. Further, to control the ingress and egress of steam, slide-valves, eccentrics, etc., are required; and in order to utilize the power of the engine, the backwards and forwards action of the piston has to be commuted into a one-directional or continuous rotary motion, by means of suitable mechanical contrivances such as crossheads, slides, cranks, etc. The reciprocating engine in its complete form is obviously then an assemblage of many mechanical devices, each more or less complex; and the multiplicity of moving parts means that a large percentage of the total power exerted by the steam on the piston is absorbed in the

engine itself, thus reducing the mechanical efficiency; and, more important still, each and every one of these parts is a possible source of break-down.

In order to secure something like steadiness of running, a fly-wheel has to be fitted; and, that it may effectually perform its function, it must be of great weight and, in the case of a slow-running engine, of large diameter also. (A not sufficiently powerful fly-wheel is worse than useless, for instead of steadying the engine, it may of itself cause irregularity.) In calculations relating to the fly-wheel, the weight of the rim only is usually taken into account, that of the arms and boss being neglected; and as the effectiveness is dependent upon the weight and velocity of the rim, it is evident that there is a large mass revolving at a considerable distance from the centre of gyration, thus the fly-wheel is particularly liable to the effects of centrifugal force. Though a well-designed fly-wheel is comparatively harmless when running at its normal speed and under fairly steady load, yet it should be borne in mind that centrifugal force varies as the square of the number of revolutions per unit of time; that a slight increase of speed means a large increase of centrifugal strain; and in the event of the engine attaining excessive speed the fly-wheel may, and sometimes does, fly asunder or burst, causing considerable damage to life and property.

The essentials for an ideal engine—that is, the one least liable to derangement and giving the maximum useful effect, are—(1) The moving parts as few and as simple as possible; (2) the motion continuous in one direction; and (3) the speed of rotation practically unlimited.

To fulfil these conditions with an engine built on the reciprocating principle is obviously an impossibility; and engineers recognizing this have devoted a large amount of skill, time and money, to the development of the rotary type. Many varieties have been introduced, including the Rigg revolving, the Tower spherical, and other less wellknown rotary or semi-rotary engines; but in spite of the undoubted ingenuity attaching to their design, they cannot be said to have met with success—largely perhaps owing to extravagance of steam consumption. In 1884, however, the Parsons compound steam-turbine was placed on the market; and though, as at first constructed, this engine also was very wasteful of steam (and had the reputation of being even worse in this respect than it was in reality, owing to the smallness of the plants then built, and perhaps to some extent also to the “disinterested statements of disinterested parties”) yet its general working was remarkably good considering its tender age, and convinced the inventor and many leading engineers that when further developed it would play a prominent part.

Experience in manufacture, the use of suitable machine-tools, and the introduction of modifications and improvements in the turbine itself, gradually overcame the initial drawbacks; until at the present day it is admitted to be equal in economy, and in many respects superior to the best engines of other types. It is accepted for the highest class of work and is largely used by the British and foreign governments, leading shipping companies, and industrial concerns of almost every kind—some 85,000 horse-power having been supplied.

Electrical engineers were the first to appreciate the many advantages of the steam-turbine engine, and they used it with great success for driving dynamos: with the result that until comparatively recently the steam-turbine was looked upon by many as being suitable for this class of work only—in fact almost as an accessory of the dynamo, and not as an engine *per se*. The great trade in this direction tended to foster the impression, and the exigencies of delivery, etc., prevented due attention being paid to the other obvious applications of such an engine. With the enlargement of the works, however, the opportunity came, and was seized, to apply it to the driving of other rotary machinery, such as centrifugal pumps, ventilating fans, etc.; or, to speak more accurately, to adapt these machines to the speed of the turbine. Long and careful experiments were made, every detail of working being noted, until there was absolutely no doubt as to the efficient and smooth working of these pumping and ventilating plants, after which some attempt was made to put them on the market. The wellknown British conservatism, and a natural shyness on the part of mining engineers at adopting a plant so radically different in construction from those to which they have been accustomed, combined with the demand in other directions on the producing capacity of the works, have hitherto prevented them from being installed to anything like the extent that they would seem to deserve; but those already at work have given entire satisfaction to the users.

The steam-turbine has since its inception been so modified, altered, and improved, that, except in principle, there is little similarity between the modern and the early forms. To trace out the various modifications, alterations, and improvements, would occupy too much time; the writer must therefore confine himself to the two most recent types—"radial-flow," and "axial" or "parallel-flow" turbines.

Radial-flow turbines can perhaps be best described by verbatim extracts from a report, dated August, 1892, by Prof. J. A. Ewing, on an engine of 175 indicated horse-power:—

A general view of the plant tested is given in elevation in Fig. 1, and in plan in Fig. 2 (Plate XXVII.). The turbine-case (*a*) contains a series of seven revolving discs, from the surface of which the turbine-blades project. They are arranged, on each disc, in a series of concentric rings. The fixed guide-plates stand in spaces between these rings, being carried by annular discs, which are fixed to the case. Thus each revolving disc, with its neighbouring fixed disc, forms a series of outward-flow turbines, the steam entering the series inside the smallest ring of blades and escaping at the circumference into a channel, which conducts it between the back of the revolving disc and of the next fixed disc to the inside of the next series of rings. The arrangement will be understood by reference to Fig. 3 (Plate XXVII.), which is a section showing the first three turbine-discs. The heights and apertures of the turbine-blades on each disc are adapted to the increasing volume of the steam, as it expands from an absolute pressure of 115 lbs. per square inch to an absolute pressure of 1 lb. per square inch. The first six discs, which are each 15 inches in diameter, are designed to expand the steam to about atmospheric pressure, the remainder of the expansion being performed in passing the seventh disc, which is 26½ inches in diameter, and has (unlike the other six) a double series of rings of blades, one series on each side, through which the steam flows "in parallel." The height to which the turbine-blades project above the discs in which they are secured varies from $\frac{1}{4}$ inch to 1 inch. The whole number of rings of moving blades in the machine tested was 35. The blades are made of strong sheet brass, and show no sign of wear after continued use. Steam enters the turbine case at one end, through a double-beat valve, shown in Fig. 3, and after passing the successive turbine-discs, is discharged at *b* (Fig. 1) to a condenser. The longitudinal pressure on the turbine-shaft, due to the one-sided character of the six smaller turbine-discs, is balanced at the high-pressure end by a revolving baffle piston (Fig. 3), with a number of deep grooves on its circumference, which are entered by corresponding projections on a fixed bush, resembling a thrust-block. Any small amount of longitudinal thrust which may remain unbalanced is received by an adjustable grooved thrust-bearing at the end of the spindle, beyond the main bearing. This, which is contained in the oil-box *c* (Fig. 3), is shown to a larger scale in section in Fig. 4 (Plate XXVII.). The thrust-bearing (*d*, Fig. 4) consists of seven collars on the spindle, revolving in a grooved bush, which is split longitudinally into halves, with separate longitudinal adjustment to allow any wear to be taken up, so that end-shake is prevented, and the endwise position of the shaft is maintained with great precision. This device also gives a means of regulating the amount of clearance over the tips of the turbine-blades. The thrust-bearing, like the main bearing, runs in a bath of oil.

The main bearings are of a special construction, which is admirably adapted to ensure easy running at high speed, and to damp out vibration. The shaft (*e*, Fig. 4) rotates in a phosphor-bronze sleeve, outside of which are slipped three concentric steel tubes fitting loosely over one another. The outermost tube *f* (Fig. 4) is a loose fit in the casting which forms the seat of the bearing. Oil is continuously and freely fed to the bearing from a cistern above, under a head of some 6 inches, and drains into a chamber below, from which it is automatically pumped back to the cistern. The oil is used over and over again. In this way the small clearance between each tube or sleeve and the one outside of it is kept charged with a film of oil, with the effect that while the shaft retains a necessary small amount of freedom to adjust itself by lateral displacement, the viscosity of the films acts as a powerful damper to prevent oscillation from being set up. The working of the bearing is perfectly satisfactory, and the damping action is so great that the shaft

may even be put considerably out of balance without causing the vibration to become excessive or making the bearings run hot. The oil-chambers are connected by pipes, so that a single oil-pump maintains the circulation in all. The pump, which is shown at *m* in Fig. 1, is driven by an eccentric which receives its motion from a worm *n* on the main shaft, working in oil, between the main bearing and thrust-bearing of Fig. 4.

The parallel-flow turbine, shown in section in Fig. 5 (Plate XXVII.), is rather more efficient than the radial-flow type, and is now the more generally used. The moving blades are fitted round the outer circumference of what may be termed a stepped barrel, comprising a series of barrels, *A*, *B*, and *C*, of different diameters, rigidly keyed to the turbine-shaft. On the inner periphery of the cylinder are fitted corresponding stationary or guide-blades, between which the moving blades revolve. The barrels *D*, *E*, and *F* are simply dummies for the purpose of preventing end-thrust, no rotative work being done by them. Fig. 5 shows three diameters of barrel, those of corresponding diameters being connected by passages in the casting in order to equalize the pressure. The diameters of the barrels, and the clearances between the blades, or steam passages, are varied to suit the increasing volume of the steam as it expands towards the low-pressure end, thus keeping the velocity of flow practically constant throughout. The steam is admitted through the double-beat valve *H*, and enters the turbine-case all round the spindle at *J*, thence flowing in each direction towards the ends of the cylinder, the impact of the steam on the moving blades causing the barrel and consequently the turbine-shaft to rotate. The bearings, shown in section in Figs. 6 and 7 (Plate XXVII.) are, as in the case of the radial-flow type, of the tubular pattern. The oiling arrangements and other details are also similar, and need not be again described.

It may be of interest here to note that each ring of moving blades taken in conjunction with its corresponding ring of guide-blades may be considered as a turbine complete in itself. The steam-turbine engine therefore consists of a large number of small turbines, at each of which expansion of steam takes place—the result being not a triple or a quadruple only, but a multiple-expansion engine.

In a steam-turbine, the steam may be expanded down to 1 lb. per square inch absolute, or even to a still lower pressure, without any material increase of frictional resistance. A very high ratio of expansion is therefore practicable, and as an increase in the number of expansions means an increase in the efficiency, it is evident that where local condi-

tions as to water-supply, etc., will permit, condensing should be resorted to, and the condenser chosen should be one giving a high vacuum. A good surface-condenser should give a vacuum of 27 to 29 inches of mercury, and, where water is plentiful, would probably be the type adopted; but where water is scarce an evaporative condenser, giving a vacuum of, say, 23 inches could be used.

The writer has frequently been told by people who confuse angular velocity with linear velocity that, owing to its high speed, the steam-turbine is most dangerous; and he particularly wishes to point out to the members that this is an utterly erroneous impression, for the turbine is probably the safest of all engines. The rate of rotation is no doubt high as compared with reciprocating engine-practice, but the weight of the barrel and its radius of gyration are both very small. Besides, the barrel is completely enclosed in the cylinder, which has an ample factor of safety, and even were the shaft itself to crack the *débris* could not fly out amongst the workmen. The writer has known turbines to run for weeks and even months at from 30 to 40 per cent. above their normal speeds, without giving the slightest trouble. Moreover, the usual speeds of turbines are from 2,000 to 6,000 revolutions per minute, whereas upwards of 32,000 revolutions has been attained. From this it will be seen that the so-called high speed is only moderate speed after all. In short, the author has no hesitation in saying that those who consider the steam-turbine a dangerous contrivance can have no knowledge of its principle and construction.

The advantages claimed for the steam turbine are :—

Simplicity, because the engine consists merely of a bladed barrel rotating inside a bladed cylinder.

An engine of 700 brake horse-power occupies only 41 square feet of floor-space.

An engine of 700 brake horse-power weighs only 89 cwts.

Portability, consequent on its compactness and lightness. No one part of an engine of 700 brake horse-power weighs more than 48 cwts.

Absence of vibration due to the motion being purely rotary and without reciprocating action.

These engines simply stand in drip-trays on any firm level bed, or even on wood trestles; and, except on ship-board, no holding-down bolts are required or used.

All parts are light, readily accessible, and freely handled, rendering repairs easy and rapid, partly due to the foregoing advantages, and also to the fact that on account of its extreme simplicity and perfect balance,

the engine seldom gets out of order. Turbines sometimes run for years and cost practically nothing in repairs and renewals.

The peculiar construction of the bearings enables them to last indefinitely. They sustain the weight only of the moving parts, and there is absolutely no thrust, so that the pressure on them is the same whether the engine is running or stationary. They run in a bath of oil, and the wear is so small as to be practically negligible.

The lubrication is automatic by means of a pump driven off the turbine-spindle—as has already been described. It will be seen that the supply of oil to the bearings varies with the speed of the engine; the lubrication is therefore perfectly automatic.

The governing is automatic, the admission of steam to the cylinder being regulated by the load. The turbine-barrel, by virtue of its momentum, acts to some extent as a fly-wheel; but it has an advantage not possessed by an ordinary fly-wheel, in that it is running in steam, which forms a cushion or brake, and softens the shock due to heavy and sudden changes of load, besides possibly aiding centripetal force.

There are no internal rubbing surfaces, packings, or internal lubrication on which superheated steam can have any deteriorating effect; superheating may therefore be resorted to, and it effects an economy of from 10 to 15 per cent. The absence of internal lubrication also leads to a saving in the upkeep of boilers and condensers.

These engines use very little oil, because there are so few rubbing surfaces. The same oil is used over and over again, being passed through a filter when it becomes gritty; and the saving in oil represents a considerable sum in the course of a year.

The admittance of water into the cylinder merely slows down the speed, owing to the steam spaces being too contracted to allow of its free passage; as the water finds its way through, the speed gradually increases again until it reaches the normal—no damage being done to the engine.

A notable feature of these engines is the small increase in the steam used per horse-power as the load decreases: the rise from full load to one-half load being only about $12\frac{1}{2}$ per cent., and frequently only 10 per cent. This economy of steam at average loads is of great importance, and it admits of larger units being installed, thus saving initial outlay and interest thereon. Another point in favour of the turbine is, that the consumption of steam does not increase after continued use. Turbines have been tested after two or three years' regular work, and the consumption of steam has been found to be practically the same as when they were first started; this is due to the fact that the steam has no

cutting action on the turbine-blades and the clearances therefore remain the same.

The absence of cylinder-condensation is an undoubted advantage, for the loss in reciprocating engines due to this cause ranges from 10 to 30 per cent., according to the class of engine and the point of cut-off.

The turbine possesses adaptability in a very high degree. It can be arranged to work either condensing or non-condensing as required, and at any steam-pressure. It is quite feasible to work a turbine with a steam-pressure as low as $1\frac{1}{2}$ lbs. per square inch—indeed the driving of turbines with the exhaust-steam from other engines is the subject of patents. Another useful feature is, that the speed of a turbine may be increased to a very considerable extent without detriment.

There is a saving in attendance, due to the entirely automatic lubrication and governing, and to the machinery being smaller, more conveniently arranged, and more readily controlled, while one man can with ease attend to several turbos.

The Turbo Fan.—The turbo fan consists of a steam-turbine coupled direct to a screw fan. The engine is of the parallel-flow type, such as that already described; the fan has a cast-steel boss and thin wrought-steel blades, and is fitted in the neck of a long cone or evasée chimney, the inner end of which is in free communication with the return-airway, the arrangement being shown in Fig. 8 (Plate XXVII.). The fan-bearing is of the tubular pattern, and exactly similar to those of the engine; easy running is therefore assured, and there is an entire absence of vibration. The engine and fan-shafts are made of special steel, and the factor of safety allowed is so large that their fracture is well nigh impossible. The lubrication is automatic, the circulation being maintained by the oil-pump worked off the turbine shaft. The motion of the engine is identical with that of the fan, both being purely rotary and without reciprocating action, thus securing the advantages of direct driving and maximum regularity, and reducing wear-and-tear to practically *nil*. There being no reversal of motion in either engine or fan, any desired rate of rotation is attainable: with the result that a high peripheral velocity and high water-gauge can be obtained with a fan of small diameter. Each plant is fitted with a mechanical safety-governor, which will effectively control the speed.

The difficulty of driving screw-fans economically and efficiently seems to be quite overcome by fitting the screw in the neck of a long cone (as shown in Fig. 8), and a very small screw will do as much work as a large fan of the ordinary type—as the following examples show:—

A turbo fan, 8 feet in diameter, running at 2,000 revolutions per minute, and giving 30,000 cubic feet of air per minute at 7 inches of water-gauge, has been in constant use night and day (except on Sundays and holidays) for about two years, at a large and well-known smelting-works near Newcastle-upon-Tyne, and has never given a moment's trouble. The engine weighs about 2 tons, the fan and spindle 10 cwts.; and the turbo fan complete weighs therefore about $2\frac{1}{2}$ tons (Fig. 9, Plate XXVII.).

A ventilating-plant at a colliery near Newcastle-upon-Tyne has a fan 5 feet in diameter and a capacity of 120,000 cubic feet of air per minute at $2\frac{1}{2}$ inches of water-gauge—the speed being 2,500 revolutions per minute. The engine weighs about $35\frac{1}{2}$ cwts., the fan and fan-shaft about 8 cwts.; and the weight of the turbo fan complete is therefore 2 tons $3\frac{1}{2}$ cwts.

The foregoing data cannot fail to demonstrate the compactness of the turbo fan, and the enormous saving effected in the matter of buildings and foundations.

The Turbo Pump.—The disadvantages of reciprocating pumps are many and serious. They are unwieldy, costly, and the valves, packings, etc., require almost constant attention—especially where gritty water has to be dealt with.

The centrifugal pump, on the other hand, is simple in construction, consisting as it does merely of an impeller revolving in a case. Among its advantages over other types may be mentioned portability and ease of erection, absence of valves, eccentrics and other contrivances which consume power in friction; economy in use and great durability; continuous and steady discharge without air-vessels; but little affected by sand, mud, grit, etc.; saving in foundations owing to motion being purely rotary; absence of vibration; and adaptability, as both quantity and head may be varied by simply altering speed.

Many engineers have the impression that the centrifugal pump is only suitable for low lifts, say not exceeding 40 or 50 feet. It is quite an erroneous one, however, for an ordinary centrifugal pump can deal with heads of 300 feet or more if it be driven fast enough; and by the compound centrifugal pump, which may be said to consist of two or more pumps in series (tandem fashion) on the same spindle, heads of 1,000 feet and upwards may be dealt with. The misconception is probably due to the fact that it is impossible to drive a reciprocating engine at anything like the requisite speed.

A turbine-driven centrifugal pump is adapted for dealing with large quantities of water and high lifts, and consists of a steam-turbine coupled direct on the same bed-plate to a Parsons high-lift centrifugal pump. The engine is of the parallel-flow type, and the coupling to the pump is effected by means of a square-bored sliding sleeve. All the bearings, of both engine and pump, are of the tubular pattern (Figs. 6 and 7), and the lubrication is similar to that of the turbo fan, being automatic, and the circulation maintained by the oil-pump driven off the engine-shaft. The pump is somewhat similar to a Gwynne, but modified to suit the higher speed at which it is driven. The pump-case is of cast-iron; and the fan, which is of manganese-bronze, can be easily withdrawn without disturbing any pipe or other joints. The spindle is of special steel, coated with brass if necessary; and, where it passes into the casing, is fitted with a special water-packed gland, and requires no attention or lubrication when running. A suitable governor is fitted to prevent the speed from becoming excessive, also an ejector for priming the pump at starting, and proper full-sized foot and delivery-valves. The water is admitted on both sides of the pump, thus avoiding end-thrust.

At first sight, it may be thought that coupling two or more pumps in series would entail a considerable loss of efficiency; but experience shows that, instead of a loss, there is a very slight increase of efficiency—due possibly to the first pump which takes the water from the sump concentrating the water that it delivers to the second or discharging pump.

The only drawback to the use of the turbo pump for mine-drainage is the necessity of carrying steam down the shaft: this has, of course, to be done, for a centrifugal pump is purely a force-pump, and suction is limited to, say, 20 feet. Where, however, this is not an objection, the turbo pump would seem to be far ahead of all competitors. (It may be mentioned here incidentally, that where electricity is available, an electric motor may be substituted for the steam-turbine.)

A turbo pump built for a mill at Lancaster is rather interesting as showing the adaptability of these plants. Its general use is to pump water into a tank, delivering, when run at 2,000 revolutions per minute, 25,000 gallons per hour against a head of 40 feet, but in case of fire it can be speeded up to 4,000 revolutions, when it will discharge about 40,000 gallons per hour against a head of 160 feet. All that is necessary to effect the transformation to a fire-pump is to adjust the governor to the increased speed, and this can be done in a moment. This plant occupies only 25 square feet of floor-space, and weighs 40 cwt. complete.

The foregoing is, however, a small plant, and its ratio of mass to output is much greater than is the case with pumps of larger capacity. As an instance of the compactness of the more powerful sets, it may be mentioned that a turbo pump complete, and capable of delivering 1,330 gallons per minute against a head of 360 feet, that is, 145 water horsepower, occupies only 30 square feet of floor-space and weighs 45 cwts.

Turbo-Electric Generators.—The output of a dynamo is proportional to the volume of the armature, the number of revolutions per minute, and the magnetic flux: from which it follows that, assuming the first and third of these factors to be constant, the output is proportional to the speed of revolution, or, in other words, by increasing the rate of rotation you cut more lines of force per unit time, and can do the same work with a smaller machine, thus reducing the ratio of mass to output.

The steam-turbine having a high rate of revolution and a very even turning moment, is excellently adapted for direct driving of dynamos. The complete plant, commonly called a turbo dynamo, is illustrated in Fig. 10 (Plate XXVII.), and comprises a parallel-flow turbine coupled direct on the same bed-plate to a high-speed dynamo, the coupling being effected by means of a square-bored sleeve. The dynamo is usually shunt-wound; that is, the coils of the field-magnet circuit consist of a large number of turns of comparatively fine wire connected as a shunt to the external circuit, and allow only a small proportion of the total current generated by the armature to pass through them: it is, therefore, always suitable for charging accumulators. The magnets are usually of the horse-shoe type, and are made of wrought-iron, or of good cast-steel. The armature may be either drum or gramme-wound, as may be preferred. (Drum-winding is undoubtedly the better when the load is fairly steady and the electromotive force does not exceed, say, 300 volts, for the weight efficiency is much higher, there is more even distribution of electromotive force in the coils, there are no inside wires to cause an internal field and increase the idle resistance, and the iron can be carried to the shaft. When, however, the machine is to be used for rough power work such as is frequently met with at collieries, and the electromotive force is, say, 400 or 500 volts, the writer prefers a gramme-wound armature, for coils of considerably different potentials are not contiguous, and there is less likelihood of insulation troubles.) The commutator is made of best hard-drawn copper, the segments being insulated from each other by mica, and held in place by massive steel rings which are shrunk on after

the commutator is built: it is therefore exceedingly strong mechanically. The brush-sockets are of the gravity type, no adjusting springs whatever being required or used.

The electrical governor which controls the speed of the turbine is a special feature; and for effectiveness and quickness of action is certainly unsurpassed, probably unequalled. It is of the direct-acting solenoid type, controlling the intermittent admission of steam, and actuated directly by the voltage. Prof. Ewing, in his report, said:—

The governing of the machine tested was accomplished by a novel and extremely effective appliance. Steam was admitted to the turbine in a series of gusts by the periodic opening and closing of the double-beat lift-valve shown in Fig. 3 (Plate XXVII.). This valve was operated by means of a steam relay in mechanical connexion with the turbine-shaft, so that the valve was opened regularly once in every 28 revolutions of the shaft. The duration of each gust was controlled by an electric solenoid, which was connected as a shunt to the field-magnets, but was compounded so as to keep the volts constant. The core of the solenoid was hung from the end of a long lever, *o*, Fig. 1 (Plate XXVII.). The fulcrum, *p*, of this lever was periodically moved up and down by means of a link connecting it with the eccentric which also served to drive the oil-pump. The short end of the lever, *q*, controlled the valve of the steam relay. Each periodic movement caused a gust of steam to be admitted to the turbine, the duration of the gust depending on the height of the distant end of the lever. The effect was, that at full load the gusts became blended into an almost continuous blast, the lift-valve closing only momentarily, or not at all, in each of the periodic movements: under any lighter load each interval of admission alternated with an interval during which the steam was completely shut off. The action of the governor was most satisfactory. The periods of admission were so frequent that they caused no material throbbing of speed nor any variation of volts sensible on a voltmeter. There was no heating, and the freedom from friction was greater than I have seen in any governor. I repeatedly threw the whole load, amounting to over 130 electrical horse-power, on and off suddenly, without causing more than a momentary variation in the volts. The governor was sensitive, quick, and certain in its action to quite an exceptional degree.

Prof. George Forbes, in his report of June, 1893, said that:—

The governing is of such an effective character, and is so prompt in its action, that it will certainly perform functions which could not be performed by other governors with which I am acquainted. More especially am I struck with the importance of using such apparatus for street-railway work. The greatest engineering trouble in connexion with electrical tramway-lines is due to the enormous variations in load when different cars are stopped and started. It seemed to me that this type of machine is pre-eminently suited for such work. All these tests show the reliability and the effective action of the governor, and its great suitability for electric traction purposes.

To deal anything like fully with the uses of electricity in mining would necessitate a paper on that subject alone; the writer must, therefore, content himself with reminding members that they are both numer-

ous and varied. At a very large colliery in the West Riding of Yorkshire with which he is intimate, the applications include underground and surface-lighting, welding, the driving of underground and surface-haulage, pumps, fans, screening and washing-machinery, hoists, disintegrator, machinery in mechanics' and blacksmiths' shops, lamp-cleaning machines, circular saws, and even the hay-chopping and corn-crushing machines, and they are about to adopt electrically driven coal-cutters also; in fact, with the exception of winding and ventilating, everything on the place is driven by electric power. It will be readily understood that a load, of which the above are the components, must necessarily be of a most fluctuating nature, and the changes at times both heavy and unexpected (at the colliery referred to, as much as 200 horse-power is frequently thrown on or off), and that to cope satisfactorily with such a load the fulfilment of the following conditions is absolutely imperative:—(a) The generator must be controlled by means of a thoroughly reliable and quick-acting governor; and (b) the principle of construction of the generator must be such that, whatever the change in the load, and however suddenly such change may occur, the generator will not suffer damage therefrom.

Experience has clearly shown, both here and abroad, that slow-running engines are unsuitable for this class of work; they do not answer the governor with sufficient rapidity, they have a very uneven turning moment, and the flywheels and belts are a source of break-down and danger. The turbo, on the other hand, would seem to be the ideal plant for power-transmission work, for it responds to sudden and heavy variations of load in a really marvellous fashion, and is not detrimentally affected thereby. When a very heavy change of load takes place there is, of course, a momentary fluctuation in the voltage, but the governor brings the engine back to its normal speed almost instantaneously. All the advantages claimed earlier in this paper for the steam-turbine engine apply equally to the turbo electric generator, and, therefore, it is unnecessary to repeat them.

A very compact arrangement comprises a turbo dynamo, fitted with surface-condenser and pumps, the condenser shell forming part of the bed-plate. These combined plants have met with much favour lately. A somewhat similar plant consists of a turbo dynamo, complete with air-pump and jet condenser, the air-pump being driven from the turbine-shaft by means of worm-gearing.

APPENDIX.

Though the subject is hardly embraced by the title of this paper, the writer believes that some data respecting the fastest steam vessel afloat—the torpedo-boat “*Turbinia*”—will be of interest, and will at the same time tend to confirm his previous statements as to the compactness and capabilities of the steam-turbine engine.

This little vessel is at the present time exciting considerable interest in naval circles; for though she is the first boat engined by the steam-turbine and, owing to sundry errors of detail, which are now being rectified, she has not so far attained her maximum speed, but she has already exceeded the record of any vessel afloat, irrespective of size, by $\frac{1}{2}$ knot, and is about 9 knots an hour faster than any boat of corresponding dimensions—the average speed made on her trials of April 10th, 1897, being 32.75 knots (about 38 miles) per hour.

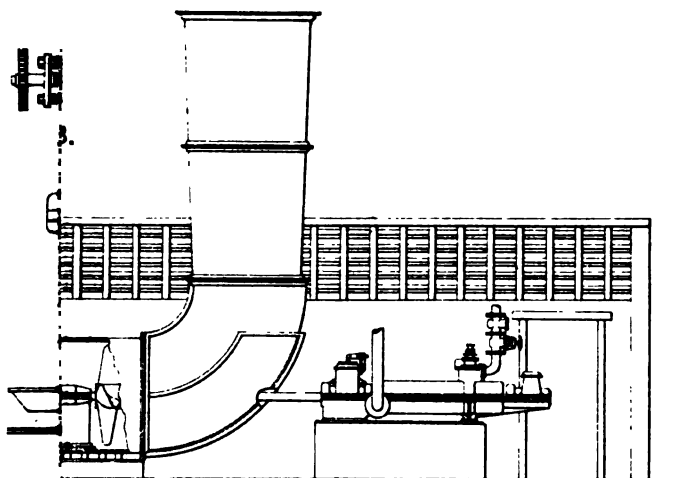
The “*Turbinia*” is 100 feet in length, 9 feet beam, and her draught amidships is 3 feet. Her total displacement is 44½ tons, made up of—main engines, 3 tons 13 cwt.; all other machinery, including boiler, propellers, condensers, shafting, tanks, etc., 18 tons 7 cwt.; hull complete, 15 tons; and coal and water, 7½ tons.

The hull and deck are of steel plate, and she is divided into five water-tight compartments.

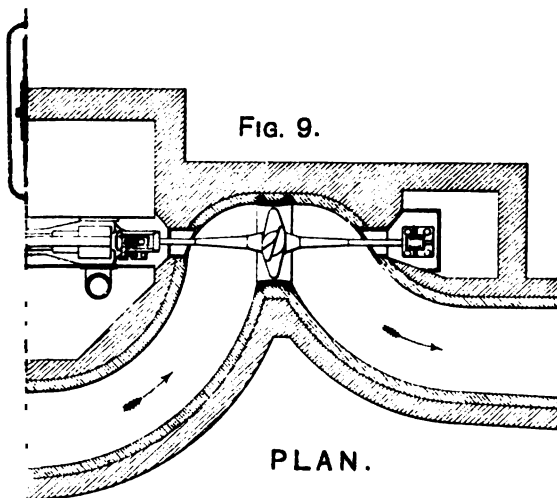
The boiler is of the water-tube type, for 225 pounds per square inch working pressure, and has a total heating-surface of 1,100 square feet, and a grate-surface of 42 square feet. There are two firing-doors, one at each end. The stokeholds are closed, and the draught forced by a fan worked from the engine-shaft. The surface-condenser has 4,200 square feet of cooling-surface, and the circulating water is supplied by means of scoops, hinged under the bilge. The freshwater tank and hot-well contain about 250 gallons. Most of the auxiliary machinery is in duplicate, and includes main and spare air-pumps, main and spare feed-pumps, main and spare oil-pumps, auxiliary circulating-pump, and the usual bilge-ejectors. There are three steam-turbines driving the three shafts: the low-pressure turbine being in the centre and the high-pressure and intermediate turbines one on either side. The steam passes through these in the usual sequence, thence to the condenser—each turbine exerting about one-third of the total power, and the steam being expanded from 170 lbs. to 1 lb. per square inch absolute. Each shaft carries three screws each 18 inches in diameter, so there are nine screws. The engines, and consequently the propellers make, when at full speed, 2,200 revolutions per minute. The thrust of the propellers is balanced by the steam-pressure in the turbines. Lignum-vitæ bearings are used for the screw-shafts.

The “*Turbinia*” has shown herself to be a first rate sea boat, and vibration is practically non-existent.

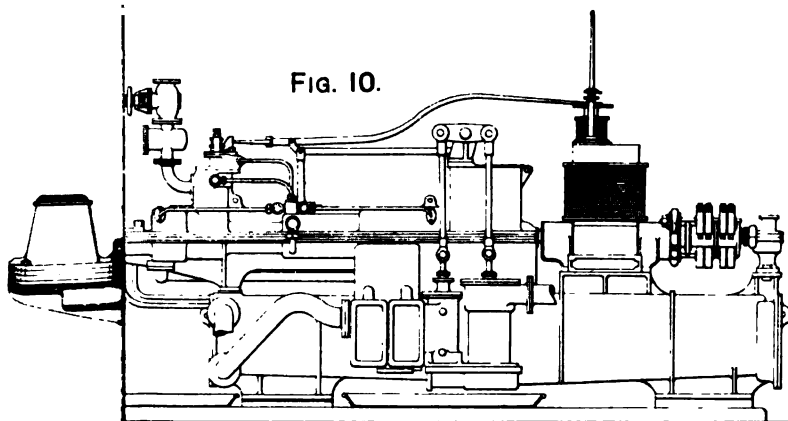
Mr. B. WOODWORTH said that he had been very much interested in the paper, which dealt with a new departure altogether. If the turbo-engine got rid of the wear-and-tear of high-speed machinery, it would have a remarkable result. He could not see but that it might be so. It was said that it would be so, and practice would prove it one way



TURBO FAN FOR COLLIERY VENTILATION.



TURBO FAN AS FITTED AT LEAD WORKS.



32 KILO-WATT TURBO PLANT.

or another. If the turbine acted as Mr. Bailie said it would, it had a great future before it. There was no rubbing surface in the cylinder, and no reciprocating motion to cause friction or vibration.

Mr. TREGLOWN said that the paper was undoubtedly a very interesting one. With regard to the immense number of revolutions, he said that it was somewhat difficult to see how durability could be attained with such very high velocities. Then, as to the matter of economy, he took it that statistics could be produced from actual working at collieries, manufactories, or other places of industry where this type of machinery is used.

Mr. PREST asked what was the consumption of steam per indicated horsepower?

Mr. BAILIE replied that when non-condensing, the steam-turbine would not compare with triple expansion, but with condensing engines it would be equal; and with engines of, say, 100 horsepower and upwards the steam-turbine would be superior to any reciprocating engine. The cylinder (or internal) friction was small, and did not increase with the increased power. They had been tested by independent engineers, and they varied according to size of plant—with a good vacuum the consumption of fuel would be from $12\frac{1}{2}$ to 15 pounds per indicated horsepower.

Mr. PREST observed that that was the best; what was the worst?

Mr. BAILIE said that depended on the working conditions.

Mr. F. SILVESTER, in proposing a vote of thanks to Mr. Bailie, said that the paper was a full and careful description of one of the most important mechanical inventions of this mechanical age, and one that would play a great part as a steam rotary motor, especially where high speeds were required. Speeds that recently would have been considered as dangerous and impossible are attained in this engine with perfect safety. He believed that more experiments and money had been spent on the rotary engine than all others; but it seemed to have been left to the present day, and to Mr. C. A. Parsons, to make the engine a perfect success. As a comparison between the turbo-engine and fan and the ordinary reciprocating engine, as applied to the ventilation of mines, an ordinary Guibal fan, 40 feet in diameter and 12 feet wide, giving 130,000 cubic feet of air per minute, with its engine bed-plates, etc., would weigh, say, 70 tons altogether; but to accomplish the same effect by the use of the turbo-engine and fan, the combined weight was, say, $2\frac{1}{2}$ tons.

The space occupied, foundations, wear-and-tear, and lubrication are all equally in favour of the latter arrangement.

Mr. C. E. DE RANCE, in seconding the motion, said that he had been very much interested in the paper.

The CHAIRMAN, who supported the motion, said that he did not quite agree with Mr. Silvester that high-speed engines of this type were going to replace the reciprocating engine for all purposes ; although it was evident that where uniform motion, as for electric lighting, and pumping or ventilation was required, the steam-turbine appeared to be a suitable engine for the work.

Mr. SILVESTER—For all purposes where high speed was required.

The resolution was agreed to.

APPENDICES.

I.—NOTES OF PAPERS ON THE WORKING OF MINES, METALLURGY, ETC., FROM THE TRANSACTIONS OF COLONIAL AND FOREIGN SOCIETIES AND COLONIAL AND FOREIGN PUBLICATIONS.

ANALYSIS OF ALUMINIUM AND ITS ALLOYS.

- (1) *Analyse de l'Aluminium et de ses Alliages.* By F. JEAN. *Revue de Chimie Industrielle*, 1897, vol. viii., pages 5-8.

Although Messrs. Moissan and Gouthière have published very complete methods of analysis of aluminium and its alloys, the matter cannot be considered as exhausted, it being important—in view of their effect on the physical and mechanical properties of the metal—to estimate accurately the (frequently very small) proportions of metals and metalloids present.

The author proceeds by treating 10 grammes of aluminium-borings with hydrochloric acid (of 10 per cent. strength) in a flask fitted with a bulb-tube containing bromine, the attack of the acid being carefully regulated. When the reaction is finished, the bromine-solution—containing, in the form of acids, all the sulphur, phosphorus, and arsenic in the metal—is heated to drive off the bromine, and the sulphur is thrown down as barium sulphate, the arsenic being precipitated by sulphuretted hydrogen. On calcination along with fuming nitric acid, arsenic acid is obtained, the presence of antimony in the precipitate being detected by its insolubility in water.

The filtrate, after being boiled, is treated with 5 cubic centimetres of nitric acid and 10 cubic centimetres of a concentrated solution of ammonium nitrate, the phosphorus being thrown down as phosphoric acid by ammonium molybdate for estimation by the Pemberton titration-method, 0.0187 of KHO being equal to 0.001 gramme of phosphoric acid.

The hydrochloric solution of the metal is diluted and passed through a tared filter to remove the undissolved residue, from which the carbon is estimated by the loss in weight on calcination, the remainder being fused with alkaline carbonates and nitre and taken up by boiling water. Silica is removed from the solution by evaporating to dryness after the addition of a little hydrochloric acid, and the residue is dissolved in aqua-regia and united to the main solution. From this solution lead is estimated (in the absence of antimony and tin) by precipitation with sulphuretted hydrogen, calcination, re-solution in nitric acid, and determination as sulphate in presence of water and alcohol, copper being thrown down from the filtrate by boiling with soda. When tin or antimony is present, the precipitated sulphides are treated with yellow ammonium sulphide, and the two metals estimated in the ordinary manner.

When the filtrate from the sulphuretted hydrogen precipitation is colourless, the absence of chromium and nickel is indicated, and it is then concentrated to 100 cubic centimetres, one-half of which is evaporated with potassium chlorate for the removal of silica. (It is well to make sure that alumina is absent from this pre-

precipitate by fusion with alkaline carbonates and re-separation.) The liquid separated from the silica is treated with 25 to 30 cubic centimetres of hydrochloric acid and titrated with protochloride of tin for the estimation of iron.

The second half of the solution is rendered alkaline by caustic soda, boiled to dissolve the alumina and treated with bromine to throw down the manganese, zinc being titrated by means of sodium sulphide.

When chromium is present, it and iron are determined from a separate portion of the metal by attacking 1 gramme with solid caustic soda at a low heat and fusing with potassium nitrate and sodium bicarbonate. The oxides insoluble in water are dissolved in dilute sulphuric acid, and after reduction by zinc the filtered liquid is titrated for iron, the chromium being determined by comparing the colour of the liquid with standard solutions of potassium chromate.

Nitrogen, if suspected, may be determined by attacking the metal by caustic soda and passing the evolved hydrogen through hydrochloric acid, from which the absorbed ammonia is estimated by titration.

For estimating sodium, it is advisable to modify the Moissan method, in so far that, instead of determining the metal from the chloride, the nitrate is converted into sulphate, and subsequently, by calcination with ammonium carbonate, into carbonate, the sulphuric acid being removed by baryta. The sodium carbonate is then titrated with deci-normal acid.

C. S.

(2) By H. GOUTHIÈRE. *Annales de Chimie Analytique*, vol. i., pages 265-270.

Copper, nickel, lead, and iron are determined by acting on 5 to 10 grammes of the aluminium with sodium hydroxide (of 33 per cent. strength), decanting the liquid and washing the black deposit with boiling water, after which it is dissolved in warm dilute nitric acid, concentrated by evaporation, mixed with a little strong nitric acid, and electrolysed at 50° to 60° Cent., the copper coming down on the negative, and the lead (as PbO_2) on the positive pole.

Iron is precipitated from the residual liquid by an excess of ammonia (to redissolve the liquid thrown down concurrently), and is dried and weighed as oxide. The filtrate is heated, and, after acidifying slightly by sulphuric acid, is again electrolysed to throw down the nickel.

Aluminium may be estimated direct or by difference, the latter being the more usual and shorter way.

Tin and antimony.—A fresh portion of metal is dissolved in hydrochloric acid, and the precipitate produced by sulphuretted hydrogen is digested with ammonium sulphide, the solution being re-precipitated by dilute hydrochloric acid. If antimony be present, it is revealed by the colour of the sulphide, and tin remains behind as bi-oxide after calcination.

Zinc is thrown down from the residual hydrochloric solution by sodium acetate and sulphuretted hydrogen, the precipitate being washed, calcined, and weighed as oxide of zinc.

Arsenic is estimated by dissolving the precipitated sulphides in nitric acid, concentrating the solution along with sulphuric acid and testing in the Marsh apparatus.

Silica.—A nitro-hydrochloric solution of the metal is evaporated to dryness until free from acid, and, after heating to about 115° Cent., digested with hydrochloric acid, the washed residue being dried, calcined, and weighed.

The total carbon is found by the Boussingault method or by the Creak and Ulgren method, and sulphur by the Rollet method or by the Eggertz colorimetric test.

C. S.

OCCURRENCE OF ARSENIC AND OTHER MINERALS IN THE COAL-MEASURES OF LIÈGE, BELGIUM.

Sur la Présence du Molybdène, du Sélénium, du Bismuth, etc., dans le Terrain Houiller du Pays de Liège. By A. JORISSEN. *Annales de la Société Géologique de Belgique*, 1895-96, vol. xxiii., *mémoires*, pages 101-105.

In examining the dust collected in the chimney of the stove at the Institut de Pharmacie de Liège, and in the flue of the heating apparatus of the Botanical Garden of the same city, the coal for which was derived from the Ste. Marguerite and Beyne collieries respectively, the author obtained the following results:—

On dissolving 1 kilogramme of the substance in aqua-regia, a solution, rich in ferric salts, was obtained, which, when treated with a solution of stannous chloride, yielded a red precipitate burning with a blue flame and evolving a disagreeable odour. This precipitate responded to the usual tests for selenium.

The solution in aqua-regia, treated with excess of sulphur dioxide (SO₂), evaporated to dryness, and taken up with hydrochloric acid, left a residue of the sulphates of calcium and lead.

The liquid yielded a copious precipitate with sulphuretted hydrogen, which precipitate was treated with sodium sulphide, and the resulting solution reprecipitated by hydrochloric acid. On treating by the Otto process for the separation of arsenic and antimony, the first-named was obtained in solution, from which it was thrown down as sulphide by means of sulphuretted hydrogen. Another sulphide in this precipitate was isolated by removing the arsenic in the condition of ammonio-magnesian arsenate, and proved to be molybdenum.

The insoluble residue from the sodium sulphide treatment was found to contain an appreciable amount of bismuth, and relatively large quantities of copper and lead. Traces of nickel and cobalt, and a notable proportion of zinc, were also detected.

C. S.

ASPHALT-DEPOSITS AT LOBSANN (ALSACE).

Gewinnung und Verwerthung von Asphalt auf dem Bergwerk Lobsann im Elsass. By DR. JASPER. *Zeitschrift für das Berg-, Hütten-, und Salinen-Wesen im Preussischen Staate*, 1896, vol. xlv., pages 387-392.

The discovery of bituminous limestone in the brown coal beds of Lobsann dates from 1789, but the utilization of the asphalt was not begun until 1820. Up to 1845, the deposits were worked by private agreement with the proprietors of the Pechelbronn concession—the Lobsann concession not conferring any absolute right to work the bitumen—but the development of the property was from thence onward retarded by reason of litigation between the two companies, which was not arranged until 1875, when an agreement was arrived at whereby the right of working and utilizing the asphalt within a zone comprising 1,176 hectares (2,906 acres) was secured to the Lobsann company.

The asphalt concession of Lobsann lies between Weissenburg and Wörth, on the eastern side of the Vosges. The Bunter Sandstone of the Vosges on the west is here separated from more recent formations on the east by a fault filled with fragments of the country-rock. These more recent formations are of Oligocene age, and consist (for the first 200 feet) of clays of marine origin, carrying *Leda Deshayesiana*; below these come a bed of soft greyish white dolomitic limestones traversed by thin netlike beds of lignite that never much exceed 1 foot in thickness, and consist chiefly of palm-remains with a few conifers. The passage

from the limestone to the clays is in places marked by a thin bed about 3 feet thick of pebbles of *Muschelkalk*, cemented together by asphaltic sandstone (*Pech-sandstein*).

Beds of limestone impregnated with asphalt occur in these lignitic limestones forming about 0.9 of the latter, which are 80 to 100 feet thick; the presence of land and freshwater snails and ungulates (*Anthracotherium Alsatianum*) proves this to be a freshwater deposit. It is not known to what depth the asphaltic impregnations may continue, except that a 15 feet bed of asphaltic sandstone is known below the limestone strata. The percentage of asphalt in the limestone-beds varies. There are four different beds, interspersed with layers of non-bituminous limestone. The hardness of the rock varies considerably, some portions being easily hewn with a pick, and others again requiring the aid of explosives for their dislodgment. Unlike that in the accompanying pitch sand, the bitumen is so closely incorporated with the lime as to be capable of extraction by hot water. At present, the three upper beds of asphaltic limestone, respectively 13, 16 and 20 feet thick, are alone being worked. The system of working is by bord-and-pillar; and the asphaltic limestone is brought by mechanical haulage through a day-drift direct to the dressing-works.

The rock is dried by steam in upright iron retorts, and, after grinding in mills and disintegrators, is sold as meal, or made up into mastic by melting along with 10 per cent. of Trinidad bitumen (or 6 per cent. of petroleum residue and 4 per cent. of Trinidad asphalt) for 12 hours at 160° to 170° Cent. in horizontal semi-cylindrical iron pans. A paving powder is prepared by drying and grinding the richest portions (containing over 13 per cent. of bitumen) of the rock. For use this is heated to 120° Cent. and beaten and smoothed by means of hot irons. An asphalt tar is made from 70 per cent. of filtered Trinidad asphalt and 30 per cent. of petroleum residue melted and mixed together for 48 hours. Finally, a small quadrangular tile 1½ to 2 inches thick, for paving footways, etc., is made by subjecting the asphalt to a hydraulic pressure of 150 to 180 atmospheres in moulds.

In 1895, the total output amounted to 3,268 tons of mastic, 248 tons of tar, 150 tons of meal, 58 tons of compressed powder, and 1,852 square metres (20,000 square feet) of asphalt tiles, the average production for the last 4 years being 3,208 tons. The removal of the prejudice formerly existing in the minds of municipal authorities, etc., against Lobsann asphalt will, it is considered, lead to an extension of its employment in Germany, which country forms at present the sole market for the products of the Lobsann works. H. L. AND C. S.

STRENGTH OF STEAM-BOILERS.

Sur un Mode particulier d'Avaries le long des Rivures de Chaudières. By G. WALCKENAER. Annales des Mines, 1896, vol. x., pages 367-386, and figures.

In the case of boilers made with lapped plates and single rivet-seams, the theoretical line of least resistance passes through the rivet-holes; but, after several accidents in which boilers have opened along their longitudinal rivet-seams, it was found that the rending of the plates had affected the inner plate, not along this line of least resistance, but along one parallel with it, between the rivet-holes and the line along which caulking had exerted a thrust between the plates.

The author describes several boiler accidents in France, in which the plates opened in the above manner, terminating with the following, which he regards as a case especially in point. Some boilers, erected near Paris about 1888, had been made of inferior plates, so that they ill withstood the strain to which they were

subjected by bending. Scarcely had they been fired, when they leaked at the longitudinal rivet-seams; and successive caulking on the lapped edge of the outer plate had the effect of "upsetting" it, as the smiths say, or of forming a shallow flange on the end, which so forced the two plates apart as to leave a space of 0.08 inch (2 millimetres) between the two. The effect of this strain upon the inner plate was to produce a crack between the centre line of rivet-holes and the upset edge of the outside plate, if indeed the crack had not been already commenced by the punching, and probable drifting, of the rivet-holes.

In the official enquiry which followed one such accident, Mr. Janet (inspector of mines) found that the edge of the outer plate had been turned up (forming an inner flange) to such an extent by caulking, that the space between the two plates was as much as 0.12 inch (3 millimetres). This injudicious caulking is regarded as the determining cause of these accidents by producing cracks, or enlarging them after they have been started, by bending, punching and drifting in plates of insufficient ductility.

J. W. P.

ECONOMICAL COMBUSTION IN BOILER-FURNACES.

Appareils pour assurer des Conditions économiques dans lesquelles s'opère la Combustion du Charbon dans les Foyers de Chaudières à vapeur. By EMILE LADURON. *Bulletin de l'Association des Ingénieurs de Liège*, 1896, vol. xx., page 11.

Two German appliances, bearing the names of "econometer" and "dosy-meter," depend upon the principle that, for obtaining a really economical combustion, care must be taken to avoid admitting into the furnace too great an excess of air, which becomes heated and passes up the chimney, carrying away with it a considerable amount of heat. In practice, a coal of medium quality, which in theory would require 128 cubic feet of air per lb. (8 cubic metres per kilogramme), really requires about 166 cubic feet per lb. (10.4 cubic metres per kilogramme) for being entirely consumed; and all the air admitted in excess of this proportion will occasion a loss of heat. Whence it is concluded that the volumetric carbonic acid content of the gases produced by the combustion should not be much lower than 15 per cent.; and, if this content be less, a calculation can easily be made as to the excess of air admitted, and therefore of the loss of heat with which it corresponds. Both the appliances above-named are sensitive balances for measuring the density of the gases, and consequently their carbonic acid content. It would appear that the indications given by these appliances should be interpreted differently for fuels of which the composition is not the same; and in collieries, especially where inferior coal with high ash content is used, it may be difficult to determine the exact quantity of air necessary for affording perfect combustion.

J. W. P.

MECHANICAL EQUIVALENT OF HEAT AND ECONOMICAL USE OF STEAM.

- (1) *Laboratoire de mécanique appliquée de la Faculté Technique de l'Université de Liège (École des Arts et Manufactures et des Mines): Rapport sur les Essais de 1896.* By V. DWELSHAUVERS-DERY. *Revue Universelle des Mines*, 1896, vol. xxxiv., pages 141-165.

The experimental investigations made during March, 1896, had the twofold object of ascertaining the economy which may be obtained by intercepting water from the steam in the valve-chest of engines, by the use of superheating, and by

steam-jacketting, and also of checking the value of the mechanical equivalent of heat, by large-scale tests on the brake which serves to produce and measure the useful resistance.

The conclusion drawn from the six trials is that the mean of the mechanical equivalent, calculated under the hypothesis that the radiation of the brake and the melting of the lubricant may be disregarded, is 780 foot-pounds per British heat unit (427·22 kilogrammetres per calorie), a figure which only differs by one-thousandth from that of Mr. Rowland. Inasmuch as the trials had the object, not only of ascertaining the calorimetric results of the brake, but also those of the engine, indicator-diagrams were taken every 5 minutes, whence the mean indicated power per revolution was deduced, which permitted of fixing the mean useful effect at 0·883; that is to say, the inherent friction absorbs about 12 per cent. of the power communicated to the piston.

The intercepting of water in the valve-chest is always economical with saturated steam, and the reverse with superheated steam. The steam-jacket effects a saving in all cases (both with saturated and superheated steam, and with and without interception of the water in the valve-chest) and superheating the steam, even to a moderate degree, also effects a saving in all cases.

The most economical working of a steam-engine is secured by superheating the steam, with the addition of a steam-jacket, and without intercepting the water in the valve-chest; and the least economical is that with saturated steam, without steam-jacket, and without intercepting the water in the valve-chest.

(2) *Étude de huit Essais de Machine à vapeur.* By V. DWELSHAUVERS-DERY. *Revue Universelle des Mines*, 1896, vol. xxxvi., pages 129-169.

The eight engine trials which gave rise to a former communication* may be divided into two series, one with saturated and the other with superheated steam; and the first two trials of each series were made without steam-jacketing, one without and the other with intercepting, in the valve-chest, the water carried along by the steam; while the two last trials of each series were made with steam-jacketing, one without and the other with intercepting the water carried into the valve-chest by the steam. The remaining conditions were so far as possible the same in all the eight trials; and the phases of steam-distribution were the same for the forward and return stroke of the piston, the steam being cut-off at 0·10 stroke without lead, and the exhaust beginning with a 0·05 of lead and finishing 0·10 before the end of the stroke.

The indicator-diagrams show, first, how great is the quantity of heat exchanged between the metal and the steam, compared with the quantity of heat corresponding with the power; and next, to what degree intercepting the water carried along by the steam into the valve-chest, in the trials with non-superheated steam, diminishes the initial condensation. On the other hand, when the steam reaches the valve-chest superheated, the use of a steam-trap brings about an increase of the initial condensation. The advantage of the steam-trap when the steam used is not superheated is made evident, as also is the loss when the steam is superheated. The effect of superheating is very marked, and that of steam-jacketing also; but the latter only constitutes a palliative and not a radical remedy. If an engine be run under the same conditions, with and without steam-jacketing, a saving will be obtained in the former case, in connexion with the total disadvantageous influence of the sides.

These trials have brought out a noteworthy circumstance, viz., that, with steam superheated to 330·8° Fahr. (166° Cent.) on entering the cylinder, and

* *Revue Universelle des Mines*, 1894, vol. xxxiv., page 141.

saturated steam at the boiler-pressure, of 311° Fahr. (155° Cent.), stagnant in the steam-jacket casing, steam-jacketing effected a saving of more than 20 per cent. by appreciably diminishing the initial condensation. This circumstance may be explained by the fact that steam in the cylinder is never homogeneous throughout; but the temperature, pressure, and steam or water state differ from one point to another, and vary constantly, because the fluid moves in tortuous passages where there are eddies of all kinds, and liquid drops are thrown forward by centrifugal force. Even during the more quiescent periods of expansion and compression the steam cannot be or remain homogeneous throughout, owing to the cold contact of the metal, of which more and more surface is exposed as the piston advances. Although the steam is certainly superheated in the centre, observations have shown that the metal surface is covered with a dew which may be abundant; and this is especially what occurs during the admission of steam. The cold sides localize their condensing action on the layer of steam in contact with their surface, just in the same manner as do the cold windows of a room containing damp air. The effect of the steam-jacket is to diminish the initial condensation, and increase the proportion of water usefully re-evaporated, i.e., during the expansion; but for this purpose the steam in the jacket must have a higher temperature than that in the cylinder, even during its admission.

J. W. P.

COAL-DUST FIRING.

Chauffage par Combustibles pulvérisés réalisant la Combustion intégrale. ANON.
L'Industrie, 1896, page 517, with figures.

Fuel economy, easy stoking, the suppression of smoke, and the certainty of steam-generation that may be regulated at will, appear to be secured by the method of "integral combustion," based on the use of powdered coal, in accordance with the Friedeberg and De Camp systems. The characteristic features of the Friedeberg system are the following:—The air blown into the apparatus, at the pressure of 12 to 16 inches (30 to 40 centimetres) of water, by means of a fan connected by pipes suitably arranged, separates into two currents, of which the first, arriving in a downward direction, passes through a valve into a quadrangular box that receives the powdered coal from a funnel, and where an intimate mixture of the air and coal-dust is effected by means of the gyratory movement of the former. The mixture is forced into a pipe, whence it is projected into the fire-box, while passing round (on either side of) a prism of refractory material. As the powder falls regularly into the mixing-box, the operation takes place in a perfectly uniform manner, so long as air is introduced into the apparatus. A second air-current, of far larger volume, passes through a horizontal pipe, and joins, in the space in front of the refractory prism, the first current charged with coal-dust, and whose force of projection before entering the fire-box it greatly increases. Valves in the two pipes permit of suitably regulating the mixtures and also the pressure to be set up, while at the same time keeping open the main valve which regulates the entrance of air into the apparatus.

The De Camp system secures the same advantages by methods which may be called contrary. At the bottom of a hopper, charged with coal-dust, is an archimedean screw, the speed of whose revolution may be regulated at will, and which effects the distribution of the powdered coal that falls on the outer surface of a small perforated drum, the more or less rapid revolution of which constitutes a second means for regulating the feed of coal. The coal-dust which falls on to the upper portion of the perforated cylinder is naturally caught up by the fan, so

that a uniform mixture of air and coal-dust is projected into the furnace. In this method, the air-current is regulated by varying the speed of the fan, and also by the degree of opening in the inlet. When this regulation is effected, the distributing-apparatus is put in motion; and, according to the speed given to the screw and drum, more or less coal-dust is fed in, so that a few instants suffice to determine the proportion required for perfect combustion.

Analyses of the products of combustion show a minimum of oxygen, the almost complete absence of carbonic oxide, and a maximum of carbonic acid. These two methods have, besides, the great advantage that the apparatus for applying them need not be in close proximity to the furnace, as the mixture of air and coal-dust may be led by metal pipes, just like coal-gas.

J. W. P.

SMOKE-CONSUMING APPARATUS, SUPPRESSING CHIMNEYS.

Appareil fumivore supprimant les Cheminées. ANON. *L'Industrie*, 1896, page 401, with illustrations.

Methods devised for suppressing smoke may be divided into two main classes:—(1) Those for preventing the formation of smoke or burning it after production, and (2) those for absorbing the soluble gases formed, and arresting the solid matters. Apparatus of the first class are based, for the most part, on a rational air-admission; and their chief advantage is that they may be adapted to all kinds of furnaces without great modification, giving good results as regards fuel-utilization, though the smoke is not entirely consumed.

Apparatus of the second class appear to have completely solved the problem. The arrangement devised by Mr. Grünwald of Holzminden, which has been applied with success to the Paris Opera House, comprises a fan for drawing the products of combustion from the furnaces, and directing them into a tank containing water, surmounted by a rising and falling cover like that of a gasometer. After bubbling through the water, in which they are partially dissolved and freed from their solid particles, the gases escape into the atmosphere or are led to apparatus for utilizing them, thus rendering a chimney unnecessary.

J. W. P.

LIESENS HAND-WORKED ROCK-DRILL.

Note sur une nouvelle Perforatrice par rodage mue a bras d'hommes (Système Liesens). By OS. DERCLAYE. *Revue Universelle des Mines*, 1897, vol. xxvii., pages 68-74, and plate.

In most existing rock-drills the man in charge is always obliged to perform a certain action in order to suppress or re-establish the forward feed of the bit; but the inventor of the Liesens rock-drill has hit upon an arrangement which permits the man to perform this action almost instinctively, and without the necessity of resorting to a brake or spanner. The ratchet arrangement, placed between the bit and the screw, consists of two ratchet-wheels, forming part, one of the screw-socket and the other of the bit-holder. One of these ratchet-wheels, for giving both rotation and advance, has only four teeth, with a large space between each two, so that the pawl actuating it slips over a large surface without exerting any action. The other ratchet-wheel, that for giving rotation, and which has twelve teeth, is worked by another pawl. Inasmuch as the screw-socket and bit-holder are independent of one another, if the man gives the ratchet-arrangement more than a quarter of a turn, the two wheels will be actuated together, giving both rotation and advance. In this action the two ratchet-wheels are worked together

by means of pawls, just as if they only formed one, so that working the ratchet-lever gives both rotation and advance. If, however, this lever only receive small portions of a turn, the pawl of the first-named ratchet-wheel will slip between two teeth and not turn the screw; but, on the other hand, the 12 toothed wheel will be alone actuated, giving the bit a rotary motion. The parts carrying the bit and the screw do not rub directly one against the other, but have between them small hardened steel balls, as in ball-bearings; and the pitch of the screw is proportioned to the hardness of the rock. When the resistance of the latter is normal, the man in charge will give the usual parts of a turn; but when the resistance increases he will only give small parts of a turn; so as to produce grinding action without advance, while he will increase their amplitude when the resistance is overcome, so as to again feed the bit forward.

This rock-drill has the additional advantage of better utilizing the power of the man working it. In rock-drills provided with a brake the power is partly absorbed by the friction when a differential movement is produced; the motive power remaining the same, one portion is absorbed by the work of drilling and the other by the brake, irrespective of the inherent friction. In this drill, on the contrary, the power is proportioned to the resistance. Moreover, in rock-drills with brakes, the wear due to friction sometimes takes place on parts that are costly to renew, which is not the case in the present instance.

J. W. P.

FAUCK METHOD OF BORING.

Ueber sein neues Bohrsystem. By ALBERT FAUCK. *Vereins-Mittheilungen: Beilage zur Oesterreichischen Zeitschrift für Berg- und Hüttenwesen*, 1897, vol. xlv., pages 54-56.

This is a system of rope-boring in which the boring-tool is lifted by a novel arrangement. The rope is coiled on a drum that can be turned by a worm-wheel and endless screw fitted with a hand-wheel; thence it passes over a guide-pulley, and thence over a sheave on the end of a crank, from which it passes over the shearlegs pulley to be attached to the boring-tool. Rotation of the crank-shaft carrying the sheave moves the upper portion of the rope, and with it the tool attached to it, up and down. This method is only applicable to stiff boring-rods or to a boring-tool working in a slide; a free-falling cutter can only be used in large boreholes, as there is no jerk such as is obtained from the lever in the other forms of boring-plant. In this system, the number of drops can be increased to 260 per minute with a drop of 3 inches, whilst the present method generally employs sixty 20 inches drops per minute.

H. L.

RAKY METHOD OF BORING.

Note sur le Procédé de Sondage du Système Raky. By MARTIN BUHRBANCK. *Revue Universelle des Mines*, 1896, vol. xxxv., pages 53-63, and plate.

More than ordinary results were obtained by the simple mechanical arrangement, adopted in the borings of the Bonne-Espérance (Gute-Hoffnung) Mining Company, Alsace, and invented by Mr. Antoine Raky, whose object was to obtain, without slot-link or free-fall appliance, a sufficient speed of fall for the boring-tool, notwithstanding the variable speed of the working or driving by crank, and also to suppress the difficulties resulting from breakage of the rods. A heavy

weight in the form of a rod carries the boring-tool, while above it is connected with the rods proper, which receive a reciprocating motion from a crank and connecting rod worked by a pulley-and-belt from the source of power. The following side of the belt passes over a tension-pulley carried by a counterweighted lever; and the rim of the driven pulley is fitted with an adjustable segment which, at the commencement of the down-stroke of the rods, strikes against the projecting end of the lever carrying the tension-pulley, and so releases the belt. The rods are raised with a gradually increasing speed, which again diminishes slowly as they near their highest position, when they descend, and then fall with a constantly increasing speed until the blow is given, on the belt being released. In this manner, the boring-tool strikes with a maximum speed at the bottom of the hole, and consequently acts with more effect than if worked by ordinary crank-action, in which case the final speed is nil. Alternative means are also described for releasing the belt; and in one of them a chain may be used instead of a belt.

The rods are carried by the beam in the usual manner, and may be lengthened as the hole deepens. With the ordinary method of regulating, there is danger of breakage during the free fall of the rods and boring-tool, because, if the tool is set too low, the recoil will break the lowest length of the rods, and if too high the *vis viva* accumulated during the descent would exert too great a tractive effort on the beam, leading to its breakage or that of the crank. These difficulties are avoided in the Raky method by carrying the bearings of the beam-trunnions on volute springs, which give a little vertical play. With this arrangement the boring-tool must be so set that, when at rest and in its lowest position, it shall not touch the bottom of the hole; but, on account of the *vis viva* set up in the heavy rod during its free fall, the tool will descend lower to the extent of the spring's compression, so that the rods are always in tension, thus preventing the danger of breakage. The beam and crank are very strong; and in the borehole the reaction is exerted solely on the heavy weight, of rod form, which is exceedingly strong.

The arrangement of springs carrying the beam-trunnions can be made to absorb the *vis viva*, not merely of the rods proper, but also of the heavy rod and boring-tool, so that there is no danger of the latter becoming jammed in fissures.

In boring with a stream of water, there is absolute certainty, with the Raky method, of the water descending to the cutting edge of the tool, so that the hole is kept clean, and the tool always strikes on the rock instead of on a mass of accumulated mud. The foreman is in constant touch with the measures, perceiving each irregularity at the bottom of the hole, so that he can avoid feeding the rods down until sure that the hole is straight. The harder the rock, the greater will be the rebound of the tool, and also the higher the speed, which may attain 80 to 90 strokes per minute, this great rapidity permitting of boring below the lining-tubes in rotten measures.

J. W. P.

LENGTH OF STROKE OF A BORING-ROD.

Ueber die Hubhöhe. By W. WOLSKI. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1895, vol. *xliv.*, pages 637-640, and figures.

The stroke of a boring-rod has been either neglected, as insignificant, or the usual stereotyped method of boring blindly followed. The author is of opinion that the length of a stroke has a great effect upon the boring. It is generally assumed that the useful effect of a blow from a chisel is proportioned to its energy. Taking this at first for granted, he compares by calculation the efficiency of percussion-boring with different lengths of stroke. The strength of a blow

certainly increases with the stroke, but it has been proved by experiment that the number of blows per minute decreases at the same time. Which of these two counteracting influences has the greatest effect on the efficiency?

The percussion-action of a chisel consists of four periods, first, raising the weight, then a short pause at the top, the fall of the weight, and a short pause at the bottom. In rope and vertical boring, and in the Canadian system, the two pauses may be neglected, owing to the high speed, and the elasticity of the boring-rod. The time the chisel takes to fall can be determined by a formula, but it is much more difficult to know the time taken to lift it. We may assume that this time is in proportion to the time of the fall; the latter varies in different systems, but in each system it is always a constant. The author proves by calculation that the increased energy of a blow, due to the greater length of stroke, more than counterbalances the loss due to the smaller number of blows. Therefore, other conditions being the same, the mechanical effect, or the efficiency of boring, increases with the length of stroke. Thus a 3 feet stroke is 1.4 times more effective than a 1½ feet stroke.

The next point to be considered is whether the useful effect of a blow is proportional to its energy. If the boring-chisel meets soft rock or clay, it penetrates until its momentum is absorbed in resistance. The blow makes a permanent hole in the rock in proportion to its energy, all of which has been absorbed in the process. But if it encounters hard rock a different effect is produced. To pierce any hole great force is required, and the borer can no longer be considered as a solid mass, but as an elastic body. Granite, basalt, hard sandstone, etc., can oppose a resistance of 100 tons without breaking. How will the elastic boring-rod behave when subjected to this pressure? If it is suddenly arrested in its downward motion, its upper part will possess a speed, the result of which will be compression of the rod, and a corresponding pressure exerted by the edges of the chisel on the bottom of the borehole. If this bottom is impenetrable, the rod will be pressed together till its whole momentum is exhausted, the final pressure being calculated from its weight and the length of stroke. Generally, however, the rock is not impervious, and the deformation of the boring-rod only continues till a certain limit in the corresponding pressure is reached. The rock then begins to give, and the rest of the momentum is expended upon it, while all the energy hitherto spent in compressing the rod is lost as far as boring is concerned. Thus the useful effect of a blow is proportioned not to its total energy, but only to its excess of energy beyond a certain point. The weaker the blow, the less energy will be available for useful work. If the momentum be so small that no excess of pressure is produced, it will have no effect. Hundreds of blows may be delivered, representing altogether a large total of work, but the boring will make no progress; one single powerful blow would be more effective.

Thus, the greater the length of stroke the better, because the heavier the blow, the less work is expended in useless crushing. Again, the longer the stroke, the longer and more certain is the effect of the chisel, and the straighter the blow. The smaller the number of blows delivered with the same efficiency is also an advantage, because both tools and labour are economized. The only real objection which can be urged against a long stroke is that the efficiency of boring is not unlimited, but a certain maximum length, to be determined only by experiment, should not be exceeded. The limit is fixed at 6½ feet. By increasing the length of stroke in one series of boring he raised the efficiency 25 per cent. The diameter of the boring-rod, whether long and thin, or short and thick, is an important point, and makes a great difference in the results, because of its elasticity.

From these remarks, which are illustrated by two diagrams, the author draws the conclusion that the efficiency of boring increases as the square root of the length of the stroke, but lighter blows may be used with soft rock, and some clays cannot be treated otherwise. In all other cases, especially with hard rock, the heaviest blows and the greatest length of stroke are essential. A short thick rod is preferable to a long thin rod of the same weight. B. D.

THE DEEPEST BOREHOLE IN THE WORLD.

*Bohrtechnische Mitteilungen über das tiefste Bohrloch der Erde, Paruschowitz 5 bei Rybnik in Oberschlesien. By BERGRAT KÖBBICH. Glückauf, 1895, vol. xxxi., pages 1,273-1,277.**

The deepest borehole at present existing in the world is known as No. 5 at Paruschowitz, near Rybnik, in Upper Silesia. Its total depth is 2,003·34 metres (6,572·6 feet), so that it exceeds that of Schladebach,† the deepest hitherto, by 254·94 metres (836 feet). This difference is, however, rendered less important because Paruschowitz is 204 metres (669 feet) above sea-level, while Schladebach is only 102 metres (345 feet) above sea-level, so that the former borehole has only advanced 102 metres (345 feet) nearer the centre of the earth than the latter.

The borehole was put down to a depth of 107 metres (351 feet), by means of a cutting edge and a stream of water, through diluvial sand, clay, and firm grey Tertiary shales. At this point, diamond boring was commenced with a crown of 171 millimetres (6·73 inches) outside diameter. The diameters of the crowns employed were successively reduced to 116 millimetres (4·57 inches) at 319 metres (1,046 feet), 91 millimetres (3·58 inches) at 571 metres (1,873 feet), 69 millimetres (2·72 inches) at 1,014 metres (3,327 feet), this diameter being maintained down to the bottom of the borehole, which was only tubed to a depth of 1,014 metres (3,327 feet); the diameter of the first tube was 320 millimetres (12·60 inches) and of the last tube 72 millimetres (2·83 inches).

After the depth of 2,000 metres (6,561 feet) had been reached, a series of accidents and breakages interfered with the further progress of the borehole, and finally led to its abandonment.

Technically, the chief matter of interest consists in the employment of Mannesmann seamless steel tubes, without which it would probably have been difficult to have reached the depth of 2,000 metres (6,561 feet). The total weight of the rods at this depth was 13 tons 15 cwts.; it took 10 hours to draw the rods from this depth, and as much to lower them in again. At this depth it was found necessary to replace the 15 horsepower engine hitherto used by one of 25 horsepower.

Boring commenced on January 26th, 1892, and by May 17th, 1893, a depth of 2,003·34 metres (6,572·6 feet) was reached, the last metre taking over three months to finish. The actual boring took 399 working days, with a daily advance of 5·01 metres (16·4 feet). The cost of putting down this borehole was altogether £3,760, or about 37s. 6d. per metre (11s. 5d. per foot), a figure that compares very favourably with that at Schladebach, where the total cost was £8,065, or £6 1s. 3d. per metre (37s. per foot).

This borehole cut through no less than 83 coal-seams, some of which were of considerable thickness, their aggregate thickness amounting to 89·5 metres (294 feet).

* See also *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1895, vol. xliii., page 636.

† *Trans. Fed. Inst.*, vol. iii., page 1,103.

Temperature-measurements were made at 64 points down to a depth of 2,000 metres (6,561 feet), these showing a rise from 12.1° to 69.3° Cent. The average temperature-increment was 1° Cent. for each 34.14 metres (112 feet). At Schladebach, it was 1° Cent. more for 35.45 metres (116.3 feet); at Sennewitz, 36.66 metres (120.3 feet); at Licht, 35.07 metres (115 feet); and at Sperenberg, 32 metres (105 feet).

H. L.

ALLOY OF CADMIUM WITH SILVER AND COPPER.

Sur un nouveau Mode de combinaisons metalliques: Alliages du Cadmium avec l'Argent et le Cuivre. By J. B. SENDERENS. *Bulletin de la Société Chimique de Paris*, 1896, vol. xv., pages 1241-1247.

Metallic cadmium, in addition to precipitating silver from its solutions (as sulphate or acetate), also enters into direct combination with the freshly precipitated silver, and forms an alloy approximating to the formula AgCd_2 , the same result being obtained—provided the silver be in the freshly precipitated condition—when the two metals are left in contact in distilled water for some length of time. The alloy is a black powder, readily oxidizing on exposure to the air, the effect of washing by hot water also being to remove a great part of the cadmium as hydrated oxide. Hydrochloric acid dissolves the cadmium with evolution of hydrogen and deposition of metallic silver. Silver-nitrate solution is unsuitable for the reaction, since it coats the cadmium with a layer of metal and retards the formation of the alloy.

In the case of copper, similar results are obtained, but the greater solubility of the copper salts enables the progress of the reaction to be carefully followed, with the result that the rate of formation of the alloy is found to be inversely as the strength of the solution. One difference is, however, noticeable, the formation of the copper alloy ceasing with the precipitation of the copper, whereas in the case of silver it continues after all the silver is thrown down.

In the case of lead, no alloy appears to be formed, the quantity of cadmium disappearing being but slightly in excess of the amount corresponding to that of the lead deposited from the solution.

C. S.

KLADNO, SCHLAN, AND RAKONITZ COAL-FIELD, BOHEMIA.

Das Steinkohlengebiet bei Kladno, Schlan und Rakonitz, Böhmen. By JOSEF JAROSCHKA. *Berg- und Hüttenmännisches Jahrbuch*, 1896, vol. xlv., pages 133-226, and 2 plates.

The coal-field of Kladno with a longitudinal extension of about 5.6 miles, and a width of 2.8 miles, is one of the most important in Austria. Its production in 1894 was 21.72 per cent. of the total production of Austria, and 58.76 per cent. of that of Bohemia. It seems to have been discovered in 1775, and its development dates from 1846. There is practically only one coal-seam worked here, which is up to 40 feet or even more in thickness in places. The roof generally consists of fine-grained sandstone; below it is sometimes a lower coal-seam, generally slaty, and not worked. Sometimes it is altogether wanting, and then the main coal-seam is only separated by a small thickness of sandstone or clay-slate from the Silurian formation. The coal-seam usually contains from 4 to 6 partings, the total thickness of which generally amounts to about 15 inches. It has been calculated that assuming the average thickness of workable coal to be about 26 feet, this district contains a reserve of 150,000,000 tons of coal. In 1873, the production was

1,210,000 tons, and in 1894 it had increased to 2,170,000 tons, the number of men employed in the latter year being 8,297, and the value of the coal being about 5,795,864 florins (say, £280,000). The export of coal in the same year was 160,000 tons.

Other smaller coal-basins that are connected with the above are described in much detail. Among these may be named the shale coal-basin of Wotwowie, which produced in 1894 about 5,100 tons of coal, and occupied 40 workpeople; the shallow seam of Schlan, the thickness of which varies from 1 foot to 3 feet 6 inches, and which, with 453 workpeople, produced in 1894 about 49,500 tons of coal. In this latter field the coal is got by a method much resembling the Welsh double-stall system.

In the Rakonitz basin two coal-seams are worked, neither of them lying very deep. It is noteworthy that the better portion of both the coal-seams is exhausted, and that the output is a decreasing one. The lower coal-seam produced in 1894 only 19,200 tons, about one-fifth of its output in 1876, and the upper coal-seam produced in 1894 only 4,900 tons, or less than half of its 1876 output. The original paper describes the coal-fields and the various owners working them in great detail.

H. L.

DOMAN AND SZEKUL COLLIERIES, NEAR RESCHITZA, HUNGARY.

Die Kohlenwerke von Doman und Szekul bei Reschitza, in Ungarn. By X. Berg- und Huettenmaennische Zeitung, 1896, vol. lv., pages 371-373.

The Doman and Szekul collieries supply coal to the iron and steel works at Reschitza.

At Doman colliery, two coal-seams of Liassic age are being mined at an average depth of 1,150 feet, the two seams being separated by 160 to 230 feet of sandstone. The upper coal-seam consists in the west of two beds, 3 feet and 5 feet thick respectively, but in the east of only one bed 5 feet thick; the lower seam is up to 10 feet thick, the seams dipping at about 60 degrees. In some places two lower seams have also been found worth working. There are three shafts, two for winding, and one for pumping. The winding takes place only up to a day-drift 1·5 miles long, through which the coals are run out by a locomotive to the coal-washing plant and coke-ovens. The main shaft is rectangular and timbered; its section is 13 feet by 6 feet 3 inches down to the day-drift, and 16 feet 6 inches by 6 feet 3 inches below that point, and is at present 1,510 feet deep, with six working-levels below the main drift. The winding-engine is of 150 horsepower, and fitted with flat ropes; the other winding-shaft is very similar, and is fitted with a similar winding-engine. The flat ropes are of cast steel, with 192 wires, weighing 23 lbs. to the fathom, and carrying 10,000 lbs. with a factor of safety of 12. Ventilation is effected by means of a Guibal fan 29 feet 6 inches in diameter and 6 feet 6 inches broad, and a Pelzer fan 8 feet in diameter.

The coal-seams are worked by sinking the shafts generally about 130 feet deeper, and then driving cross-measure levels to cut the seam, at the same time continuing an incline from the level above; after holing, a main level is driven in the seam and a return airway some 20 feet above it. From this level, rises are driven to the level above, and the areas thus formed are divided into pillars by levels parallel to the main level. These pillars are then robbed, working from above downwards. When the thickness of the seam exceeds 6 feet 6 inches a method of stowage has to be adopted.

In the day-drift, sets of 40 to 50 tubs are formed, which are run out by a locomotive; electricity is shortly to be introduced to replace steam in this drift. The

gauge of the rails is 2 feet 3½ inches, and the tubs are of iron, weigh 7·4 cwts., and carry 14 cwts. of coal. The annual production is 60,000 to 70,000 tons.

At Szekul colliery, the general arrangements are very similar. Four coal-seams are being worked whose respective thicknesses are 2 feet 7 inches, 3 feet 3 inches, 4 feet 7 inches, and 6 feet 7 inches. The main shaft, used for both winding and pumping, is 1,365 feet deep. The winding-arrangements and haulage are identical with those used at Doman colliery. A Pelzer fan, 8 feet 2 inches in diameter, is used for ventilation; it is driven by a horizontal 50 horsepower engine, makes 250 revolutions per minute, and exhausts 35,300 cubic feet of air per minute with a watergauge of 2·16 inches. The output is 60,000 tons annually.

Both mines use Wolf benzine safety-lamps, which give every satisfaction.

H. L.

COAL-FIELDS OF FÜNFKIRCHEN, SOUTH HUNGARY, AND THE BANATE, SOUTHERN CARPATHIANS.

Die Kohlenfelder bei Fünfkirchen in Süd-Ungarn und im Banater Gebirgsmassiv, Süd-Karpathen. By Dr. J. H. KLOOS. *Zeitschrift für Praktische Geologie*, 1897, pages 148-156.

The coal-fields of Hungary belong to three widely distinct ages, the Carboniferous, the Mesozoic, and the Tertiary, the most important being those of Liassic age. The Liassic coal is best known at Fünfkirchen, lying to the west of the Danube, and separated from the Carpathians of the Banate by the broad plain of the Theiss. The geological structure of Fünfkirchen is, however, similar to that of the Banate. The strata, of Lower Liassic age, strike south-west and north-east, and consist of alternations of clay, slate, and sandstones, with subordinate occurrences of marly strata containing lenticular masses of blackband ironstone, the whole overlain by coarse conglomerates. This formation is 800 metres (2,625 feet) thick, and contains over 100 coal-seams, with a total thickness of about 50 metres (164 feet); 25 to 30 of these seams are said to be workable, averaging 0·8 to 1·3 metres (31 to 51 inches) in thickness, but increasing to 4 or exceptionally to 10 metres (13 to 33 feet). This formation is known over a length of some 15 kilometres (9 miles). The coal is suitable for coke and briquette-making, and forge, locomotive and gas-works use; the yield of coke is 75 per cent., and the ash varies from 6 to 25 per cent. In 1895, this field produced 427,600 tons of coal, whilst the Banate coal-field produced 400,000 tons, three-quarters of which was of Liassic and one-quarter of Carboniferous age.

In the mountains of the Banate, the coal-bearing Liassic formation plays an important part, and can be followed without interruption for over 50 kilometres (31 miles), its breadth being 10 kilometres (6 miles). At some places, for instance, at Resicza, the Carboniferous formation, containing 4 seams, with a total thickness of 5·2 metres (17 feet), is being worked, and above it, at Domán, the Lias, which is only separated from it by a thick bed of Permo-Triassic red sandstone, contains several important coal-seams that are being actively worked. There are several regions in which coal-mining has commenced, but the great natural facilities are somewhat neutralized by the want of suitable means of transport. The coal-bearing measures lie at steep angles, from 30 to 60 degrees, and form ridges intersected by steep valleys, so that workable backs of 500 to 600 metres (1,640 to 2,000 feet) above adit-level are obtainable. Wood and labour are both very abundant and cheap, and both roof and floor are usually very strong. The coal of the various districts gives 81 to 90 per cent. of coke and 5 to 15·5 per cent. of ash, and is anthracitic in character.

H. L.

COAL AND IRON IN UPPER SILESIA.

Die Oberschlesische Bergbau- und Hüttenindustrie. By — BREMME. Zeitschrift des Vereines deutscher Ingenieure, 1896, vol. xl., pages 1185-1186.

The occurrence of hard coal in Upper Silesia constitutes an essential factor in the successful development of the other mineral treasures of the district. The richness of the coal-layers, especially between Gleiwitz and the border, is surpassed by no other field of equal size on the Continent, the worked seams averaging 10 to 25 feet (3 to 7 metres), and sometimes attaining 30 to 40 feet (9 to 12 metres); those of 39 to 58 inches (1 to 1½ metres), looked on as large in other districts, being here often left unworked.

The coal itself is very clean, and with a low percentage of waste; the amount of sulphur is usually much below 1 per cent. Nevertheless, the greater portion, though well suited for heating purposes, is but ill adapted for coking, only a small amount being found as clod-coal, which is the nearest approach to the true coking-coal met with in this region. Generally speaking, the bituminous character of the coal decreases from the sole upwards and from the west eastwards in the Zabrze-Myslowitz series. The best coking-coal is obtained from the lower seams of the Königin Luise pit, in the extreme west of the deposit. Here and there, where the cover-rock is more than usually impervious, moderately good coking-coal is obtained from the upper seams, but the amount is insignificant; and, so long as the two classes of coal are mixed together with the idea of increasing the output of coke, so long will the quality of the product remain inferior.

Iron ores are not Crown property in this district, and the mines are mostly owned by large landed proprietors. In 1895, some 470,000 tons of brown ironstone were raised, more than half of which came from the Henckel mines, which are leased to a limited company. Another source of iron is the ferruginous dolomite found in the Muschelkalk formation.

Where the brown ironstone occurs as stuff-ore it contains 50 per cent. and more of iron, but it is mostly earthy, and in that condition has only 35 to 40 per cent. when dry, or 20 to 30 per cent. in the natural moist state. Some 2 to 3 per cent. of zinc increases the difficulty of smelting, the bye-product thereby obtained being insufficient compensation for the trouble entailed. A more valuable associated metal is silver-lead, which yields a good profit.

The present output of pig-iron in Upper Silesia amounts to about 568,000 tons per annum, from 11 works with an aggregate of 26 blast-furnaces, which is equivalent to a production of 60 tons per furnace per diem. Of this quantity, 61 per cent. is puddle iron, 7 per cent. Bessemer iron, 22 per cent. Thomas iron, 2 per cent. spiegel iron, and 8 per cent. foundry iron. C. S.

UPPER SILESIAN COAL-FIELD.

Das Oberschlesische Steinkohlenbecken und die Verjüngungsverhältnisse seiner Schichten. By C. GAEBLER. Zeitschrift für Praktische Geologie, 1896, pages 457-461, with sketch-map.

The Upper Silesian coal-field forms a rectangle of about 5,600 square miles area, the four corners of which are respectively at Tost in Prussia, Golonog in Russia, and Tenezyniek and Königsberg in Austria; by far the greater portion of the field lies in Prussian Silesia. The whole field forms one huge basin, that may be divided into a broad central basin and a narrow peripheral one separated

from the former on the west by a fault with a throw of about 1,600 metres (5,000 feet). This fault seems to be a portion of the great Orlau fault, which is probably the most important dislocation discovered as yet in strata of Carboniferous age, ranging from 2,000 to 4,000 metres and averaging about 3,000 metres (say about 10,000 feet). On the north, the outer basin is separated from the central basin by a fold; it is not certainly known whether a similar phenomenon occurs on the south, where the Carboniferous formation is overlain by extensive Tertiary developments, but there seem to be reasons for believing that such may be the case. The bed-rock of the basin consists of *grauwacke* on the west and north-west, and of Devonian limestone on the east and north-east; it is as yet unknown on the south.

The Coal-measures are divisible into two groups, well marked palæontologically, but having between them a transition series of uncertain position. The lower group is continuous throughout the entire field, as is shown by its outcrop all round the edges. The central or transition group only exists in the western portion in the deepest-lying parts of the basin, but east of the great fault is found everywhere. The upper beds are wanting in the western outer basin, but cover the northern edge basin, and above all the central basin; they are absent to the east of the main fault.

The lower group is well developed at Ostrau and Rybnik in the south-west, where it is 4,100 metres (13,000 feet) thick, and contains about 61 workable coal-seams, with an average total thickness of 63 metres (205 feet) of coal; there are altogether 185 seams, but two-thirds of these are too thin to be workable. At Golonog, in the extreme north-east, 90 kilometres (55 miles) away, this formation is only 500 metres (1,650 feet) thick, and contains 5 workable seams, totalling 7 metres (23 feet) of coal.

The middle group is 260 metres (850 feet) thick, with 7 workable seams and 26 metres (85 feet) of coal at Zabrze in the west; at Zagorze, on the extreme east, 30 kilometres (19 miles) away, it is only 17 metres (55 feet) thick, and contains 1 workable seam 14 metres (45 feet) thick. The upper coal-seam is still imperfectly known, but appears to pinch out from south to north, or in a direction at right angles to the lower formations.

The mode of thinning out and of the production of lenticular deposits is related to the mode of formation of the coal-seams. The modern theory of the origin of coal-seams looks upon these as *autochthonous*. If a wide, shallow lagoon be supposed to be elevated so that its bottom becomes dry, plants will immediately begin to grow in the rich soil, and their remains will in time form a layer of vegetable matter of greater or lesser depth; if water again flows in, owing to a depression of the lagoon, and more particularly of its mouth, the vegetable layer, or as much of it as lies beneath the water-level, will be covered by a layer of mud, which will form a wedge or cone, the greatest thickness of which will be at the point where the stream enters. At this point the coarser particles will be deposited, whilst the finer ones are carried farther away from it; hence we find that where these strata are the thickest they consist mainly of sandstones and conglomerates, and, where they are least developed, of slaty beds of very fine grain. Should the water again retreat the newly-formed cone of mud would be laid bare and a second layer of plant-remains might form, giving rise to a second coal-seam; if the previous bed of coal had also been partly exposed the second bed would form directly upon it, and the two would form a single seam, with a parting in the direction of the mouth of the ancient lagoon. In order to be able to identify coal-seams, it is thus first of all necessary to determine the conditions under which the

various strata have been deposited. The author has accordingly studied the forms of these cones of sedimentation, and constructs curves which he calls "isopachs," connecting all those points where any one group of beds has the same thickness. From these curves he deduces the position of the opening and the direction whence the currents came; and having determined these for one group, it is easy to extend the data to others, and thus by means of these isopachs he correlates the various coal-seams.

H. L.

WESTPHALIAN COAL-MINES.

Notes d'un Voyage dans le Bassin houiller de Westphalie. By — ROBIAUD. *Bulletin de la Société de l'Industrie Minérale*, 1896, vol. x., pages 241-293, and many figures.

This paper contains a description of the surface-arrangements at the leading pits of Westphalia. The systems more especially examined are the Koepe system of winding, cylindrical drums with counterbalance rope, spiral drums, and cylindrical drums with flat ropes of aloes fibre. Elaborate calculations of the various elements entering into the mechanical theory of each system of winding are embodied in the paper.

The various companies working in the Westphalian coal-field have combined to form a syndicate; it is administered by a council, each member of which represents an annual output of 1,000,000 tons, and which fixes the production of each mine and the price of the various kinds of coal. By this means, the orders being distributed by the syndicate, the selling charges and office expenses of the mines are reduced to almost nil. This syndicate has just been renewed for another 10 years; it secures to the various companies a reasonable profit per ton, and does away with competition. The companies are thus able to support the additional rates and taxes, which amount to about 9d. per ton.

H. L.

EXPLORATIONS IN THE NORD AND PAS-DE-CALAIS, FRANCE.

Official Reports of the Mine Inspectors to the French Government, by H. KUS, July 5th, 1896, and E. DUPORCQ, Arras, July 31st, 1896.

Nord.—The year 1895 was marked by interesting explorations, undertaken with the object of proving the possible continuation of the Dover coal-field. The Calais-Dunkerque Company, under the direction of Mr. Breton, put down a borehole at Gravelines, which left the Secondary rocks at the depth of 1,148 feet (350 metres) and entered grey schists, which have some analogy with Coal-measure shales, but are probably more ancient; the hole was stopped in this formation at the depth of 1,444 feet (440 metres) without having encountered a trace of coal. A boring, undertaken by the Aa Company, struck the same formation at Bourbourg-Campagne, at the depth of 1,142 feet (348 metres), but has not been continued. The Dunkerque-Cassel Company is putting down two holes: one at Arnèke, attained the depth of 393 feet (120 metres) on June 15th, 1896, and the other at Petite-Synthe, which was down 794 feet (242 metres) at the same date. The Calais-Dunkerque Company put down a hole at Ghyvelde, east of Dunkerque, which had attained a depth of 206 feet (63 metres) on June 23rd, 1896.

At the other end of the Nord coal-field, the boring at Estreux, of Messrs. Breton & Hermary, was down 721 feet (220 metres) in February, 1896, without having left the Devonian measures.

Pas-de-Calais.—The borehole put down by the Clarence-Company was stopped at the depth of 1,779 feet (542·5 metres), having cut—between 1,232 feet (391

metres) and the bottom—six coal-seams, varying in thickness from 14 inches (35 centimetres) to 4 feet 8 inches (1·45 metres), giving a total coal thickness of 17 feet 11 inches (5·5 metres). The Ferfay Company continued to the total depth of 1,893 feet (577·2 metres) its Camblain-Châtelain boring, which struck the Coal-measures at the depth of 1,468 feet (447·5 metres), while from 1,755 feet (535 metres) downwards coal *débris* were frequently found.

The Coquelle borehole, put down by the Calais-Boulogne Company to the south-west of Calais, attained the depth of 1,410 feet (429·89 metres), having cut (below the Devonian) grey schists, which are regarded as of Silurian age. The Aa Company undertook, in this department, five holes, including one near Offekerque stopped at 1,268 feet (387 metres), which cut (below the Tertiary and Secondary rocks) at the depth of 1,126 feet (343·5 metres) red and sometimes green argillaceous shales attributed to Upper Devonian.

J. W. P.

WURM COAL-FIELD.

Le Bassin de la Wurm et sa Population ouvrière. By FRANZ BÜTTGENBACH. *Revue Universelle des Mines*, 1896, vol. xxxiv., pages 232-235.

Although the Wurm coal-field extends over an area of less than 19 square miles (50 square kilometres) its importance is considerable, because it constitutes the westernmost colliery district of Germany, extending to the north of Aix-la-Chapelle, and being separated from the Eschweiler coal-field by an upthrow of the lower rocks. While this last-named coal-field only produces bituminous coal, that of the Wurm chiefly contains non-bituminous. The seams are much disturbed, being folded into characteristic zigzags; and the numerous faults and fissures traverse the basin in all directions.

The main *Feldbiss* fault traverses, almost at an angle of 90 degrees, the general direction of the seams, with a dip of 80 to 85 degrees to the east, and a mean thickness of 131 feet (20 to 60 metres), extending north and south over the whole length of the coal-field. Up to 1847, it was considered that this fault formed the eastern limit of the basin; but it has since been ascertained that, owing to this enormous fault, the Coal-measures have been thrown down from 820 feet (250 metres) to 1,312 feet (400 metres) on the eastern side, and that, under thick strata of Cretaceous, Tertiary, and recent formation, they occur again with a number of seams which exceeds by 32 those of the western side.

The boundary of the coal-field forms an approximate circle; and the *Feldbiss* fault, passing through the centre, divides the basin into nearly equal parts, that on the west forming the region of the non-bituminous coal, which has been known and worked for nearly eight centuries, and that on the east, the region of the bituminous coal, which has only been known for a period of forty years.

A portion of the coal-field, which is situated for the most part in Prussia, extends into Holland; and this circumstance gives rise to two peculiarities which are probably unique in mining geography. There is a drift 656 feet (200 metres) below the surface between the Dutch concession of Prik and that of Voccart in Prussian territory; and at the point where it passes the frontier there is an iron grating, which is sealed by the authorities of the two countries for the prevention of smuggling, as the drift only serves for the ventilation and drainage of the mine. Another large concession, belonging to Holland, and worked by the Aix-Maastricht Railway Company, extends into Prussia, the government of which has renounced all right of control over the workings.

The mean yearly production of the coal-field is 2,000,000 tons in Prussian and 110,000 tons in Dutch territory, the respective number of hands employed being 7,500 and 400. Working underground is only permitted from the age of 16; and the mean superannuation age is 49. The average period of work does not exceed 22 years; but there are a few miners who have worked 50 years and upwards. The men work, as a rule, 8 hours per day, without including the time occupied in going down and coming up. The mean daily wage is 2s. 5d. (3fr.); but many men make double that sum and even more.

J. W. P.

COAL AND IRON IN SOUTH RUSSIA.

La Région minière et métallurgique du Midi de la Russie. By MICHEL LEVITZKY.
Revue Universelle des Mines, 1896, vol. xxxiii., pages 91-122.

As regards fuel, the country is ensured from want for a long time to come. Notwithstanding the great increase in the iron industry, the price of coal has not only not advanced, but has even diminished considerably, through the opening of new collieries.

The Donetz coal-field, which occupies the southern portion of the Kharkov government, the eastern portion of that of Ekaterinoslav, and the eastern portion of the Don-Kossacks' territory, is one of the largest in Europe, extending over nearly 8,550 square miles (22,500 square kilometres). The coal-seams are rarely more than 5 feet 10 inches (1·8 metre) thick; and those which do not exceed 2 feet 11 inches (90 centimetres) often consist of pure coal only, while thicker seams always contain intercalated bands of schist and psammite. The coals vary greatly from splint coal to anthracite; and each variety has its own region. For instance, splint coal is only found in the north-west basin, near Lissitchansk. The gas and forge coals occur in a narrow zone between the caking and non-caking coals; and those which yield good blast-furnace coke occupy two large independent basins, while the semi-anthracite forms a transition from the caking coal to the anthracite, which extends over the whole south-west of the Donetz coal-field.

The composition of the various coals is given in the following table:—

Description of Coal.	Volatile Matter and Water.		Carbon.		Sulphur.		Ash.		Coke.	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Splint ...	37·6	50·1	37·7	55·2	0·6	5·15	1·28	8·1	49·1	55·1
Gas ...	27·8	37·4	50·5	67·4	0·5	2·3	1·1	7·0	58·3	70·4
Forge ...	28·4	30·6	60·2	72·4	0·25	1·6	1·3	4·0	69·4	72·9
Coking ...	12·4	23·5	66·6	85·1	0·4	3·1	0·9	8·3	70·3	87·1
Semi-anthracite	10·2	20·3	73·5	87·5	0·2	3·0	1·5	6·2	78·4	89·6
Anthracite ...	4·2	11·4	83·4	91·0	0·6	2·9	2·0	9·0	90·7	95·8

In most cases, the high ash and sulphur contents render necessary careful washing of the coal before coking. At the Berestovo-Bogodoukhovo collieries, which may be regarded as producing the typical coals of the country, the coal contains, after washing, water, 2·36 per cent.; volatile matter, 19·84 per cent.; fixed carbon, 72·91 per cent.; sulphur, 1·94 per cent.; and ash, 3·95 per cent. (ash 8 per cent. and sulphur 3 per cent. before washing); while the coke obtained from the washed coal contains on an average 0·91 per cent. of sulphur and 5·25 per cent. of ash.

In 1893-4, the Donetz coal-field produced 4,400,000 tons of coal, the value of which at the pit-mouth varied from 4s. 11½d. (6 francs 20 centimes) to 7s. 6d. (9 francs 30 centimes) per ton; but carriage to the ironworks nearly doubles the price, so that, taking into consideration loss in washing and all expenses, the ton of coke comes to about 27s. (33 francs 75 centimes) at the blast-furnaces.

Iron ore, in the form of brown hæmatite, occurs abundantly in the east of the Ekaterinoslav government and in the Don-Kossacks' territory, at Styla, Karakouba, and Sophievka; and it may be said generally that the deposits of iron ore distributed over this region are sufficient for supplying the blast-furnaces for a long period. Most of the deposits, however, are but of slight extent; and the ore requires careful picking, while it is not very pure. The following analyses are given by Mr. Kamensky of the ores smelted at the Hughes iron-works:—

Composition.	Novo- troitsa.	Nico- laiev.	Styla.			Karakouba.			
			No. 2.	No. 16.	No. 4.	No. 5.	No. 51.	No. 7.	No. 8.
Ferric oxide (Fe_2O_3) ...	76.14	71.43	71.43	70.0	64.29	73.0	73.0	76.14	73.0
Silica (SiO_2) ...	8.7	17.5	12.0	20.0	16.0	13.3	14.4	7.5	8.0
Alumina (Al_2O_3) ...	5.0	4.0	5.98	5.0	8.0	—	—	3.5	3.1
Sulphur (S) ...	—	—	—	—	—	—	—	—	—
Phosphoric acid (P_2O_5) ...	1.0	0.438	0.13	0.25	0.09	0.1	0.115	0.167	0.77
Manganese (Mn) ...	—	—	4.0	—	8.0	—	—	—	—
Lime (CaO) ...	2.35	0.335	—	—	—	—	—	3.0	7.0
Metallic iron ...	53.0	50.0	50.0	50.0	45.0	51.0	51.0	53.0	51.0

The Sophievka mines, recently discovered, are, however, of far greater extent; and their ore is stated to be very pure. The most important mines to which the country owes the development of its iron manufacture, are those of Krivoi-Rog in the Kherson government, on the banks of the Saxagane and Ingouletz rivers. The highly inclined stratified seams of quartzite contain 40 to 45, and even 48, per cent. of iron, among which occur deposits of richer ore (oligist and magnetite), containing as much as 60 and 65 per cent.—sometimes even more—of iron in pockets of lenticular form, the major axes of which lie in the same direction as the quartzite-seams.

J. W. P.

DONETZ COAL-FIELD, RUSSIA.

Le Bassin houiller du Donetz. By ARTHUR MONSEU. *Revue Universelle des Mines*, 1897, vol. xxxvii., pages 159-204 and 227-289, and vol. xxxviii., pages 25-78.

After describing the history, physiography, geography, and inhabitants of the Donetz district, the author gives an account of the coal-field in the third section of his memoir.

The strata consist of schists, sandstones, grits and limestones of Carboniferous age, in places cropping at the surface, in others overlain by Tertiary, Cretaceous or Permian strata. The beds form saddles, more or less irregular, traversed by numerous faults. The author gives several classifications of the various seams. According to one system, the coal-field may be divided into four groups:—(1) The eastern group, which is the most extensive, and contains only seams of anthracite; (2) the northern group, containing semi-anthracites, non-coking coals, and coking coals; (3) a group on either side of the Kursk-Kharkov-Azov railway, containing coking, partly coking, and non-coking coals; and (4) the western group, includes

the Kalmiova basin, which has been largely developed in recent times on account of the high quality of some of the seams; to the south of this group, about Elenovka, the coal is non-coking, pyritic, gassy, and liable to spontaneous ignition.

The total number of seams is not definitely known; it is estimated at 46, with 118 feet of workable coal. The area of the coal-field may be taken at 15,500 square miles, or more than double that of the known Carboniferous formation of Britain; it is, however, poorer than the coal-fields of Western Europe, both with respect to the number of workable seams and of their total thickness, resembling rather in this the coal-fields of North America.

The shafts are often inclined, square or rectangular in cross section, the dimensions being as much as 11 feet 9 inches by 16 feet 5 inches. They are often laid with double lines of rails, and worked by hauling-engines, the slopes being in some cases about 20 per cent. In the new shaft of the Central Donetsk Colliery there are three compartments, two being used for winding, with a section of 11 feet 10 inches by 6 feet 10 inches; these are intended to take double-decked cages, with 4 tubs in a cage, each tub carrying 7 cwts. of coals. The daily output of this shaft is expected to be 1,200 tons (in 24 hours). There are some vertical shafts, brick-lined, mostly elliptical in cross section.

The Coal-measures of the Donetsk carry but little water, being generally overlain by impervious beds of alluvial clay; there is therefore but little water to be raised. Many of the mines are free from gas, and are lit by ordinary oil-lamps; in some of them fire-damp has, however, been found. Ventilation is either natural (which is unreliable), by furnaces, by Koerting steam jets, or by Ser or Guibal fans.

The methods of mining depend upon the thickness, and especially on the dip of the seams. In the flatter seams bord-and-pillar working is usual, the pillars being from 42 to 70 feet in the side. In summer time, during the harvest, labour is scarce; hence it is usual to drive narrow workings in the winter time, and to get the broken during the summer, so as to keep up a fairly uniform output. The mine proprietors own the surface, so that they pay no attention to surface-damage; the method of working admits of coal being got on both day and night shifts, but is open to the objection of making a great deal of small.

Steeply inclined seams are worked by overhand stoping, the height of the stopes being 8 feet, and each stope leading the one below it by 13 to 16 feet; 16 stopes are thus opened between successive levels, which are driven in pairs. Every 13 to 16 feet a pass is left and timbered, down which the coal is run into tubs. This system makes much small, and, instead of it, inclined self-acting planes with cages, 200 to 260 feet apart, are being introduced; between each pair of inclined planes is a shoot or an incline for bringing in rock for filling up.

Longwall is worked in a few pits on the Lieven and Smolianinov seams, 47 and 51 inches thick respectively, dipping northwards from 10 to 20 degrees, the roof being good. The faces are 1,000 to 1,500 feet in length; a night shift kirves and nicks the coal, the next shift wedges or blasts it down, and a third shift sets the timber at the face. Another method, but little used so far, is that of vertical slices.

From the average of a large number of figures, it would seem that the cost of coal-getting, everything included, is about 5s. per ton, whilst the average selling price is about 8s. The annual output of coal (1896) from this coal-field is about 4,500,000 tons.

H. L.

MINERAL AND LIGNITE DEPOSITS OF TERUEL, SPAIN.

Les Gisements métalliques et lignitiformes du Gouvernement de Teruel (Espagne). By J. KERSTEN. Revue Universelle des Mines, 1897, vol. xxxviii., pages 125-166, with maps, plans, and sections.

The district of Teruel forms part of the ancient kingdom of Aragon, and embraces the valleys of the Ebro and the Guadalaviar or Turia, together with a series of mountain-chains rising to a height of over 5,000 feet. The geological structure is rather complex; the backbone of the country consists of Jurassic and Cretaceous rocks overlying Devonian and Silurian strata; whenever the latter come to the surface the absence of the Carboniferous formation is evident, thus proving that true coal is absent throughout the entire province. Outcrops of Primary rocks are rare; of the Secondary rocks, those of Triassic age, consisting chiefly of conglomerates, sandstones and shales, only appear in some places. They carry no minerals of any economic importance. The Jurassic formation is the most largely represented, and encloses the pyrolusite deposits of Camanas, and probably of Ojos Negros. By far the most important is the Cretaceous formation, which covers about 30 per cent. of the surface of the province, and contains all the most important deposits of mineral, such as the lignites of Andorra, Gargallo and Utrillas, the jet of Alliaga, the galena of Segura and Armillas, the pyrolusite of Crivillen, and the calamine of Linares. Two subdivisions of the Cretaceous formations are represented, namely, the Aptian and the Cenomanian; the former is of importance as containing beds of lignite intercalated between yellow limestones and marls. This lignite forms an extensive basin, the limits of which are not exactly known; it crops out at Andorra, Utrillas, and Alliaga in a very mountainous district. There seem to be two distinct deposits; that of Andorra and Gargallo is brownish-black, compact, with an even and dull fracture. Three beds are known at Andorra, but there may be more; the encasing rocks are sandy grits, overlain by a bed of greenish marl, the thickness of these beds of rock being from 16 to 20 feet, and their dip 32° south-west. An old shaft at Gargallo cut five seams, ranging from 3 feet 3 inches to 5 feet 6 inches in thickness.

At Utrillas, four seams of lignite are visible, varying from 2 feet 8 inches to 10 feet, the lowest being the thickest; while there seems to be a fifth still lower seam. These seams are separated by beds 80 to 100 feet in thickness, the general dip being 28° north-east. This lignite is black, with a bright conchoidal fracture, and no trace of fibrous structure. As a fuel it is superior to that of Andorra and Gargallo, and it occupies the base of the Aptian beds, whilst the latter occurs in the upper portion. Each of these deposits seems to constitute a perfectly distinct basin.

The Cenomanian beds contain pockets of pyrolusite at Crivillen.

Tertiary strata of Miocene age are confined to the bottom of the river-valleys; they lie horizontally, and are traversed in places by veinlets of gypsum that have been mined in places.

In the whole province of Teruel, mining is carried on in the most rudimentary manner, and the output is extremely small. Manganese occurs in pockets of apparently limited extent, and is worked on a small scale either by means of small, tortuous, irregular adits, or by shafts fitted with windlasses. The lignite-mines are worked in a similar way, the system of working being by a zigzag level driven in the seam; most of the mines use shafts and windlasses; some are opened by irregular levels, through which the mineral is carried to the surface in baskets. The author estimates the annual production of each mine at 57 tons, there being

21 mines in operation. The governmental statistics give 120 tons of lignite as the output of the entire province, but this is greatly understated by the mine owners with the object of escaping the payment of royalties. There is little demand for lignite or any other mineral product in the province, means of communication are defective, and cost of carriage high; hence there is no prospect of these mines assuming any importance in the near future. H. L.

ANTHRACITE IN GUARDO, SPAIN.

La Antracita de Guardo. ANON. *Revista Minera, Metalurgica y de Ingenieria*, 1897, vol. xlviii., page 11.

Deposits of anthracite are being opened at Guardo by the Euskaro-Castellana Company, who have rented there an area of 2,073 hectares (about 4,900 acres). There are 40 seams known in this coal-field, and their thickness is such that the above area must contain several millions of tons of coal. The coal is a true anthracite, of specific gravity 1·36, and its composition is shown by the following table:—

Seam.	Ash.	Volatle Matter.	Carbon.	Calorific Power, Calories.
Madariaza ...	3·96	3·73	92·31	6,985
Fernanda ...	7·72	2·78	89·50	6,782
Mariana ...	2·36	3·00	94·64	7,204
Civila ...	3·09	2·75	94·16	7,153

H. L.

COAL IN SIBERIA.

Sur les Résultats des Recherches du Charbon Minéral, récemment faites en Sibirie.
By General VENUKOFF. *Comptes Rendus de l'Academie des Sciences*, 1896, vol. cxxiii., page 518.

In connection with the Trans-Siberian railway, 4,722 miles (7,600 kilometres) long, which is being made at the cost of the Russian government, several scientific missions have been appointed, the geological explorations having special importance as regards the fuel supply of the railway. Up to the beginning of last year, 54 groups of workable coal or lignite-beds had been discovered, giving one deposit for every 87 miles (140 kilometres) of line, which would suffice were their distribution uniform. In Western Siberia, between the Ural and Altai chains, there are no coal or naphtha deposits along the line of way, while timber is rare, so that it became necessary to seek supplies farther afield. The railway commission therefore organised explorations on a large scale, extending to the shores of the Okhotsk Sea, where both coal and gold have been found. The following are the seven principal groups of coal-deposits already discovered in the region traversed by the railway:—

Kirghiz Steppes.—A little to the south of the railway, the nearest coal-deposit is that of Gratchevo; but the richest in coal of good quality is that of Djaman-Taou, while the mineral is also found at Taldyskoul. The coal of these deposits may be conveyed by the Irtish and Ichime rivers to Omsk and Petropaulovsk, important stations on the Trans-Siberian railway.

Altai.—The Kouznetzk coal-field contains numerous deposits both of Jurassic and Carboniferous age, the seams sometimes attaining a thickness of 13 feet (4 metres). Several deposits in the Kouznetzk district have also been explored, the coal of which contains from 65 to 70 per cent. of carbon and no sulphur.

Yenissei Basin.—In this district, there are numerous deposits, especially in the valley of the Yenissei river not far from Krasnoyarsk, where the lignites of Tertiary formation commence, a better coal being found along the banks and at the mouth of the Lower Tounjouzkat. Large deposits of free-burning lignite occur in seams $6\frac{1}{2}$ feet (2 metres) thick along the banks of the Oka, a tributary of the Angara, especially near the confluence of the Zima with the Oka.

Baikal Chain.—Coal is found at several points on both slopes of the Baikal chain, especially in the Angara valley, to the north of Yakutsk, and in the neighbourhood of Oussolie. Coal-seams also occur on the south-west shore of Lake Baikal, at the mouth of the Mourine and in other places. Coal-deposits, the geological age of which is not yet determined, have long been known to exist in the valley of the Selenga between the towns of Selenginsk and Verkhneoudinsk.

Beyond the Yablonoi Mountains.—Near the sources of the Amur and its upper tributaries coal-deposits are frequent, though they have not been explored; and several deposits have been known to exist since the eighteenth century, this being the case with that of the Oreï, where lignite is found containing pieces of well-preserved wood, and also with those of Kouloussoutaï and Douroï, discovered in 1742, the latter being well situated for transport.

Amur Valley.—The Amur Valley and those of several of its tributaries are rich in coal. In the valley of the Zeya, near its confluence with the Silindja, is found an inferior mineral; and in the Boureya valley almost vertical seams have been proved in three or four places. In the neighbourhood of Innokentieva, on the Amur, several lignite-seams, 3 feet 3 inches (1 metre) thick, are worked by the inhabitants; and on the lower Amur a series of seams, together 6 feet 6 inches (2 metres) thick, has been discovered. Near Vladivostok, a terminus of the Trans-Siberian railway, coal deposits abound, while they also occur on the shores of the Japan Sea, in the Gulfs of Possiet and Oussouri, in the valley of Souifoun, at the mouths of the Sedimi, Mangougai and Amba-Bira, in the island of Poutiatin, on the shores of the Strielok and Olga Bays, and at other points.

Saghalien.—Coal has been largely worked for 40 years in Saghalien; and at the present time attention is being specially directed to the deposits discovered in the immediate neighbourhood of the gold-mines on the shores of the Okhotsk Sea.

J. W. P.

HONGAY (TONKIN) COAL-FIELD.

Les Charbonnages d'Hongay, Tonkin. By FÉLIX BRAED. *Mémoires de la Société des Ingénieurs Civils de France*, 1897, vol. i., pages 81-112, and illustration.

The coal-deposits of the Hongay district occur along the shores of the Bay of Along and Port Courbet, about 25 miles from Haiphong. The development of the concession was commenced in 1888, and proceeded until 1892, when an incursion of pirates put a stop to the work for some months. Since that time, however, operations have been pushed on rapidly.

The coal-measures extend in a north 70° east to south 70° west direction, overlying Carboniferous Limestone and Devonian formations resting on micaceous and quartzose schists overlying the primitive granite, and consist themselves of conglomerates, sandstones, and schists, more or less coloured by iron oxide and enclosing the coal-seams.

The district is divided into two chief working centres—Nagotna and Hatou—the other discoveries of coal at the Marguerite mine, Charlot, and Campha being too far away from the railway to render their development profitable at present.

At Hatou, two seams have been proved, the upper and thicker one being some 164 to 197 feet (50 to 60 metres) in total thickness, the actual thickness of coal ranging from 98 to 131 feet (30 to 40 metres), and the dip varying between 16 and 47 degrees. It is characteristic of these coals that they do not contain a single intercalated band of schist, the layers of coal and schist being entirely distinct. The Hatou beds are believed to be identical with those discovered at Charlot, and the two together are estimated to contain 50,000,000 tons of coal.

At Nagotna, 12 seams have been identified, the four chief being:—(1) Marmottan seam, 72 inches of pure coal, dipping between 10 and 30 degrees, and containing 2.08 per cent. of ash. (2) Chater seam, 13 feet thick, or 12 feet of pure coal; ash, 2.2 to 2.6 per cent.; and dip, 30 to 50 degrees. (3) Bavier seam, 12 to 13 feet thick; pure, hard, flaming coal, without slate; ash, 2.2 to 2.8 per cent.; dip, from 15 to 30 degrees and 30 to 50 degrees. (4) Ste Barbe seam, 19 to 20 feet thick, or, after deducting the three bands of slate, a nett thickness equal to 17½ feet of friable coal, containing 2.5 to 3.5 per cent. of ash; dip, 50 to 60 degrees.

Tables of comparison between the composition of Hongay coal and that of the chief coals from Cardiff, Japan, Borneo, Australia, etc., used in the East, are given, the percentage constitution of Hongay coal being: carbon, 89.29; hydrogen, 3.36; oxygen, 2.34; nitrogen, 0.99; sulphur, 0.45; ash, 2.08; and water, 1.49; volatile matter is 6.69 per cent., and the coke 93.17 per cent. The inference is that these coals are close-burning anthracite, with a very low proportion of ash, hydrogen, and sulphur.

As regards cohesive power, tests made in accordance with official regulations at the arsenal at Haiphong—by placing 1 cwt. of coal, broken into lumps about 18 ounces in weight, in a cylinder divided by longitudinal partitions and rotated at the rate of 50 turns per minute during 2 minutes, the amount remaining within the cylinder being multiplied by 2 to give the percentage of cohesion—showed a result of 30 to 34 per cent., Cardiff coal giving 34 per cent., and Newcastle coal 38 per cent. under the same conditions.

The first briquettes made at the Hongay works had a cohesive power of 62 per cent., which was subsequently increased to 69 per cent. Tested for evaporative power and ash, these briquettes gave 3.477 lbs. of steam per lb. of fuel, at a pressure of 48 lbs. per square inch, and 21.81 per cent. of cinders and ash.

At the Nagotna mine, the work consists in driving headings at different levels connected by inclines, and packing the goaf after the coal is removed. In the Marmottan seam, operations have been pushed to a depth of 65½ feet (20 metres) below the level of the sea, without any infiltration of sea-water, though the latter approaches within 164 feet (50 metres) at high tide. The coal is raised by a winch to a height of 32.8 feet (10 metres) above high-water mark and conveyed by trucks to the fixed screens. The coal of the Chater and Bavier seams is got by sloping cuts, the under one, 6½ feet (2 metres) high, being taken out and packed before the upper one is commenced. In the Ste Barbe seam, the method of working consists in cutting horizontal uphill lifts and packing the goaf completely; the workings here are above high-water mark.

The Kestner shaft, 433 feet (132 metres) deep, and 12 feet 4 inches (3.75 metres) in diameter, has been sunk at these workings, to intersect the Bavier, Chater and Marmottan seams, and three others below, and by a cross-heading to open up the Ste Barbe seam and the superior beds. The sinking was carried out by native workmen in 8 hours' shifts under the direction of a single European, who was on duty day and night. A fair rate of progress was maintained, 63 feet (19.2 metres) being sunk in a month, and the shaft was lined with 9 inches (22 centimetres) bricks backed with concrete. The water in the pit is cleared by means of a

Worthington pump capable of raising 150 to 250 gallons per minute to a height of 656 feet (200 metres). From the Chater seam, communication has been established with the shaft by an incline, sloping at an angle of 30 degrees, and a cross-heading, 230 feet (70 metres) in length; and a similar work has been commenced in the Bavier seam. There being no fire-damp, naked lights are used throughout the workings.

A number of movable inclined planes have been provided in the mine, and similar arrangements have been made at the surface—owing to the great irregularity of the ground—for collecting the empty skips from the screening-apparatus and returning them to the shaft.

The Hatou workings are at a distance of $6\frac{1}{2}$ miles (11 kilometres) from Hongay, the two places being connected by a metre-gauge railway. Owing to the absence of intercalated schists, the coal does not need to be separated by washing. The ash does not exceed 3·3 per cent., and in many of the beds is as low as 1·8 per cent. The coal lying near the surface is won by removing the soil, the coal being then taken out by underhand stopes, breaking down the upper layer by means of long wedges.

The workings are divided into two fields, north and south, the latter being again divided into an upper set on a level with the loading-shoots, and a lower set, the coal from the latter being brought up to the shoots on automatic inclined planes. The schists are discharged from each cutting.

Owing to the heavy rainfall, in the wet season both boilers of the pump have then to be regularly in work, but in the dry season the pump need only be worked at intervals.

In removing the upper soil, galleries are driven, and the pillars broken by blasting; an excavator, the bucket of which has a capacity of 39 cubic feet (1,100 litres), is also employed, and found highly advantageous, being able to break through bands of hard sandstone up to 10 inches in thickness, and to remove blocks of stone weighing up to $\frac{1}{2}$ ton. The *debris* is loaded on to trucks drawn by buffaloes or pushed by native workmen, and the average clearance effected under ordinary conditions amounts to about 10,000 cubic feet (280 cubic metres) of earth per diem.

The northern portion of the workings is separated from the other by an unworked portion known as the central field, traversed by a double-track tunnel, 460 feet (140 metres) in length, which conveys the coal from the lower levels down to the shoots, that from the upper workings being carried down an automatic inclined plane. The cuttings already made aggregate some 6,500 feet (1,800 to 2,000 metres) in length, with an average width of 16 feet (5 metres). They are being pushed forward in both directions, the coal being taken out from above, where the amount of *debris* per ton of coal is small; but when the limit of profitable working in this way is reached, underground headings are driven, and the coal taken out from them is replaced by packing with material from the surface. The inconvenience of the open-air workings is experienced in the wet season, a land-slide of some 2,120,000 cubic feet (60,000 cubic metres) in extent having occurred in 1894, which retarded operations for eight months.

The daily average productive power of the entire staff of coolies is $\frac{1}{2}$ ton of coal per man, and, as their pay averages 17 to 20 cents, the cost of labour per ton of coal is therefore 34 to 40 cents.

Two metre-gauge railways run from Hongay to the mines, the older one, $2\frac{1}{2}$ miles (4,200 metres) in length, leading to Nagotna; that for Hatou, 6 miles (9,600 metres) long, branching off at about 1 mile (1,800 metres) from the terminus. There are 4 locomotives and 120 trucks, each holding 8 tons; 12 to 14 trucks being the average load of a train; and this rolling stock is sufficient to transport 200,000 tons of coal per annum.

The Hatou coals are screened at Hongay by 4 oscillating-screens, gauged to produce two classes of coal—from 0 to 0·60 inch (0 to 15 millimetres), and from 0·60 to 1½ inches (15 to 32 millimetres) in diameter, the plant being driven by a 30 horsepower engine. The small coal is stored in a large heap, the screened coal being discharged by a crane on to a trap-door above the trucks which convey it to the wharf. This latter is the best arranged in the East, the platform, 262 feet (80 metres) long by 52 feet (16 metres) wide, with a perpendicular platform 65 by 36 feet (20 by 11 metres) connecting it with the quay. Even at the lowest equinoctial tides there is a depth of 20½ feet (6·3 metres) of water alongside, and 32 feet (9·8 metres) at high tide. Two 7 tons Walker hydraulic cranes, on a 13 feet 1½ inches (4 metres) gauge track, lift the 4 tons boxes from the trucks and tip them into the hold of the vessel loading. A 40 horsepower engine charges the 60 tons accumulator driving the cranes and capstans for drawing the full and empty trucks whilst on the wharf. From 1,200 to 1,500 tons of coal can be dealt with in 10 to 12 hours' time.

A briquette-works has been started at Kowloon, occupying an area of about 237,000 square feet (22,000 square metres) and provided with a granite-quay 850 feet (260 metres) long for the reception of the small coal and loading the briquettes. There are two double Middleton briquette-presses, a Carr disintegrator, elevators, kneaders, a distributor composed of a vertical cellular plate, and a carrier for the finished briquettes.

For kneading, superheated steam is employed. The engine-cylinder is 13 inches in diameter, and the piston has a 33 inches stroke, with a speed of 65 revolutions per minute.

The briquettes measure 9 by 6 by 5 inches (23 by 15·4 by 13 centimetres), and weigh 12½ to 12¾ lbs. (5·6 to 5·8 kilograms). A smaller size, 6·6 lbs. (3 kilograms) in weight, can also be made. The output is 80 tons per day of 9 hours.

A Japanese caking coal is mixed with the Hongay anthracite, 10 per cent. being used, along with 9 per cent. of dry pitch and 1·5 per cent. of tar. The product contains: carbon 74·61, volatile matter 17·23, ash 6·02, and water 2·14 per cent.

Another briquette-works is being erected at Hongay, near the coal-screens, in which Couffinal presses will be used. The caking coal for the briquettes will probably be derived from the Yen Bay mines, on the Red River. This coal, containing 65 to 70 per cent. of carbon, 25·5 to 30·5 per cent. of volatile matter and moisture and 3·5 per cent. of ash. California asphalt and Sumatra petroleum residue, may furnish substitutes for pitch.

Assuming an annual output of 150,000 tons, the cost price per ton of Hongay coal placed free-on-board export vessels is computed at \$1·50, whilst the present sale prices are \$2·30 for small coals and \$5 for screened coal. The actual capacity of the mines is estimated for the current year at 130,000 tons from Hatou and 30,000 tons from Nagotna; and it is believed that the output at the former workings can be increased by 25,000 tons every year, so that in five years' time the annual production may be 300,000 tons.

C. S.

COAL-MINES OF THE TRANSVAAL.

Note sur les Mines de Houille du Transvaal. By EMILE LAPIERRE. Bulletin de la Société de l'Industrie Minérale, 1896, vol. x., pages 383-408. and 2 plates.

The coal-seams of South Africa, and especially of the Transvaal, form more or less lenticular deposits in the grits and shales of the Karoo formation. The coal-bearing strata rarely exceed 160 feet in thickness, and the seams of coal are not

numerous, being generally between two and four in number. Their thickness varies from a few inches up to 20 or even 25 feet. The stratification is horizontal. The coal-seams are not subject to many disturbances; faults, properly speaking, do not occur, but "nips" exist in which the seam is at times completely pinched out.

Transvaal coal is generally very inferior, and usually contains 22 to 24 per cent. of ash; the average approximate composition of Boksburg coal is as follows:—

	Per Cent.
Water at 100° Cent.	5·41
Volatile matter	17·10
Fixed carbon	51·79
Sulphur	3·50
Ash	22·20

Near Middelburg, better coal occurs, such as the gas coal of Maggie's mine, which contains only 4·2 per cent. of ash, and gives a good firm coke.

Most of the Boksburg coal is employed in the gold-mines of the Rand, which consumed 450,000 tons in 1894; at present 191 tons of coal are required to produce 1,000 ounces of gold.

The most important coal-mine of the Transvaal, the Brakpan mine, belonging to the Coal Trust Company, Limited, is described somewhat in detail. It has two shafts, of which the main shaft alone is used as a winding-shaft; this shaft is rectangular, 8 by 6 feet, timbered with sets of squared Norway pine, 8 inches square, set 4 feet apart. From the shaft runs a main gallery, 17 to 19 feet wide, and of about the same height (the thickness of the seam). It is fitted with endless-rope haulage. Roads are set off at right angles to it, about 150 feet apart; and these are crossed by others parallel to the main roley-way, also 150 feet apart. These blocks of 150 feet square are then cut up into smaller blocks, the method of working being by pillars 15 feet square, every alternate one of which is removed, the other being left to support the roof; the latter is very strong, and practically no timbering is used. The coal is kirved in the middle of the seam in a band of soft coal or schist; and in the absence of the latter, kirving is performed by means of dynamite. The top and bottom coals are then blasted out. Natural ventilation alone is used, and no fire-damp has ever been met with.

At the surface, the coal is first screened and the duff taken out; it is then hand-picked and sized into lump, medium and nut coal. The former is loaded in bulk by hand; the two latter qualities are filled into sacks holding 200 lbs. each. It takes over 200 natives to deal with the 1,200 tons of coal hoisted daily from the main shaft.

Brakpan colliery has been opened up with extraordinary rapidity, having produced 327,000 tons of coal in the sixth year of its existence, and commencing in 1896 with a daily output of 1,200 tons.

The work is done by natives under European supervision; the former receive £3 to £3 10s. per month of 28 days, together with rations and housing, costing, say, 8 to 10 shillings per month. The Europeans receive 16s. to £1 per day. The proportion is about 1 white man to 16 natives.

The cost of coal in bags to the company is about 5s. 6d. to 6s. per ton, and its selling price is uniformly 9s. 6d. on waggons at the colliery; its cost at the gold-mines averages 18s. per ton, the average distance of railway carriage being 15 miles.

The author criticises adversely the method of getting the coal adopted in this and all other coal-mines of the Transvaal.

The Transvaal collieries, started only a few years ago, have rapidly developed owing to the gold-mines, which they have greatly aided, their importance having increased commensurately. The capital which has been sunk in them, amply remunerated, will attract further capital ; and, thanks chiefly to the quality of the coal that some of the mines possess, and to the railway, which affords access to the large market of the Indian Ocean, the coal of the Transvaal appears likely to figure honourably in the industry of the world.

H. L. AND J. W. P.

COAL IN ONTARIO.

Coal Discovered in Ontario. By A. McCHARLES. The Engineering and Mining Journal (New York), 1896, vol. lxxii., page 52.

An important discovery has lately been made in the Sudbury district. Until the publication of Mr. Bell's map of the nickel belt in 1892 the rocks of the Sudbury district were supposed to be too old for the existence of coal, being mostly of Laurentian and Huronian origin.

But in the trough between the two main nickel ranges there is one oblong area of Cambrian formation, consisting of dark-coloured sandstones and black slates, about 10 miles wide and some 40 miles in length, extending in a north-easterly direction from the township of Trill almost to Lake Wahnapiatae. In this Cambrian strip, a few miles south of the railway and 15 miles west of Sudbury, a prospector looking for gold has discovered a bed of anthracite, very clean, compact, and said to be equal in quality to Pennsylvania hard coal. The extent of the deposit has not been ascertained yet, but the outcrop is over 20 feet in width. If this coal-deposit be of permanent depth and equal in quality to the surface-samples it will prove of immense benefit to Ontario, which now has to import all the coal used in the province.

J. W.

THE COAL-MEASURES OF THE APPALACHIAN SYSTEM, U.S.A.

The North-eastern Bituminous Coal-measures of the Appalachian System. By GEO. S. RAMSAY. Transactions of the American Institute of Mining Engineers, 1895, vol. xxv., pages 76-83.

The Appalachian system contains the largest area of all known coal-fields, extending in one direction for about 950 miles. After alluding to the general dips of the measures and the probable causes which have made them follow certain main directions, and remarking that the coals are to be found in the synclinals, while in many cases they have been eroded off the anticlinals, the writer divides the Coal-measures into five groups.

(1.) Conglomerate, at one time considered the base of the Coal-measures, containing no workable coals. In recent years, however, some valuable seams have been worked on the outcrop, although no workable coal-seams have yet been found in the centre. The thickness of the groups varies from 170 feet in Pennsylvania to as much as 1,400 feet in West Virginia. The rocks are generally composed of very hard sandstones, and, being practically indestructible, furnish good building-material.

(2.) Lower Coal-measures, containing valuable beds of coal up to 6 feet in thickness, chiefly worked round the outcrops, but containing in the centre of the field lower veins which will some day be of great value.

(3.) Barren Measures, containing but little workable coal, and averaging 600 feet in thickness.

(4.) Upper Coal-measures, containing among other seams the great Pittsburgh bed, 10 to 20 feet in thickness, which has been slowly eroded until it is only found in isolated patches.

(5.) Upper Barren Measures, amounting in places to 1,100 feet thick, and containing one main coal-bed.

A. W. G.

FOLDS AND FAULTS IN PENNSYLVANIAN ANTHRACITE-BEDS, U.S.A.

By BENJAMIN SMITH LYMAN. *Transactions of the American Institute of Mining Engineers*, 1895, vol. xxv., pages 327-369, and numerous illustrations.

The author has reproduced a number of cross-sections taken from the Pennsylvania Geological Survey, and proceeds to discuss the various theories connected with the folding and faulting of this region.

With regard to the law that the flexures of a simply undulated tract exhibit their steeper slopes almost invariably directed to one quarter, he points out that of the 177 sections taken 43 per cent. have equal slopes on the two sides, 42½ per cent. have steeper north-westerly, and 12½ per cent. steeper south-easterly slopes. On dividing the whole region up into the four fields of the Geological Survey, the percentages of equal and steeper dips is found to vary in each field, and not to follow this law with any degree of regularity.

He quotes Mr. Bailey Willis's paper on "The Mechanics of Appalachian Structure" at some length, showing how these folds were probably caused. It seems evident that the faults arise from the folding of subordinate groups of beds between stiffer ones. The extent of the faults depends, like that of the subordinate folds, on the firmness of those subordinate groups, and cannot in the same region much exceed the limits observed in the numerous cases taken to illustrate the paper.

The illustrations seem to point to the following conclusions:—(1) Steep northerly dips are much less prevalent in the Pennsylvania anthracite-region than was formerly supposed; (2) the dips in nearly half the basins and saddles are about symmetrical, and nearly three-fourths of the subordinate ones are so in the Western Middle field, but less than a-quarter of the main ones are so in the Southern field; (3) the subordinate folds throughout the region are confined to subordinate groups of beds of inferior firmness, and are not parallel to the main folds; (4) the faults are almost invariably longitudinal or reversed faults, occasioned by the overstraining of subordinate folds, and corresponding in three-fourths of the cases to an overturned southerly dip, with the upthrow to the south; (5) such broken subordinate folds, whether dipping southerly or northerly, ride in equal number on the northerly-dipping and southerly-dipping sides of the main folds; (6) the "stratigraphical throw" (that is, the shortest distance from a layer on one side of the fault to the same layer on the opposite side) averages only about 62 feet, and never exceeds 160 feet; and (7) the "displacement" (that is, the distance along the dip of the fault between the two edges of a faulted bed) averages 72 feet, and never exceeds 240 feet.

A. W. G.

* *Thirteenth Annual Report of the United States Geological Survey*, 1891-92, part II., pages 217-282, and plates.

BROWN COAL IN TEXAS, U.S.A.

Texas Brown Coal. By E. T. DUMBLE. *The Engineering and Mining Journal* (New York), 1896, vol. Lxii., page 343.

The extent of the brown-coal deposits and lack of other fuel-supply in the southern portion of Texas caused an inquiry to be made, the results of which were published by the Survey in 1892, under the title of "Brown Coal and Lignite." This report gave also the results of investigations into the methods of using similar fuels in different parts of Europe. As the mines were opened up and better coal obtained the brown fuel came more and more into use, until to-day it may be said to have fairly won a place as one of the most valuable sources of fuel-supply in the state of Texas.

It was first tried under stationary boilers, and was pronounced a success. Small changes were made in the grate-bars to increase its efficiency, and in 1895 it found ready sale to the various cotton-seed oil-mills, water-works, electric-light and power works, cotton compresses, and as a fuel for burning bricks. Latterly its use has extended to the railways for stationary engines, switch, passenger and freight engines. The comparative value of the brown coal and bituminous coal, as given in the above-mentioned report, viz., as 7 to 10, is fully borne out in practice. In engine-performance it is found that 1.4 tons of brown coal yield the same results as 1 ton of Indian Territory coal. Taking the cost of the two fuels into account, this means a saving of fully one-third of the former fuel-bills by using brown coal. The author thinks that, before this fuel attains its best development, plants must be erected for converting it into compressed fuel, so as to decrease its tendency to fall to pieces on exposure to the air.

J. W.

GEOLOGICAL MEANING OF TREE-STUMPS FOUND AT RIGHT
ANGLES TO COAL-SEAMS.*

La portée géogénique des troncs-debout. By the Rev. G. SCHMITZ. *Annales de la Société Scientifique de Bruxelles*, vol. xx., page 113.

The term *troncs-debout* (upstanding stumps) is applied to petrified tree-trunks, which are often found in Belgian colliery-workings, occupying a perpendicular position with respect to the direction of the stratification; and these stone cylinders often reproduce on their surface the exact form of the bark, while the splaying out of the base shows clearly at which end the roots occurred. This definition is perfectly independent of all movements subsequent to the deposit of the Coal-measure sediments; and it matters little, as regards the geological signification, whether the seam be approximately horizontal or be highly inclined.

All upstanding stumps must not be attributed to the method, by transport, of coal-formation; but upstanding tree-stumps may exist that have been brought from a distance, as well as others found in the spot where they grew (*in loco natali*), so that, without minute examination, the mere presence of standing stumps must not be regarded as favouring one or other hypothesis of coal-formation.

Although, at first sight, the finding of a large stump at right angles to the sediments (with its splayed-out base indicating the place of the roots) may suggest ideas favourable to the autochthonous theory, these conditions of deposit are perfectly reconcilable with that of transport. First of all, the perpendicular

* *Trans. Fed. Inst.*, vol. xi., page 585.

position of the stump does not necessarily imply that it has never left the place where it grew. Inasmuch as tree-trunks are larger below than above, and the weight of the stump may be increased by roots, it is reasonable to suppose that a current of water may have set them down upright upon their base, provided that other causes did not contribute to lay them on their side. While the number of standing trunks is infinitesimal, compared with that of those found in a recumbent position, it may be supposed that the former have been less macerated (so as to have better preserved their form and structure), owing to various causes, including a shorter period of being drifted along. It may be added that the base of a tree-stump is often found spread out in a seam of greater or less thickness, containing a large number of recumbent trunks; and both these categories of trunks may belong to the same geological deposition, some of them less resisting and more attacked having arrived flattened and recumbent, while the base of the others, better preserved, has been deposited upright in the midst of the rest spread out like a sediment.

It would be very strange, supposing that most of the standing trunks really grew in the place where they were found, that branches should never be seen adhering to them, and very rarely roots, or rather radicles, which appear to shoot out from the trunks, even the largest. It is also remarkable that, among all those trunks which are cited in support of the autochthonous theory, not one proves what would be most important to prove, viz., the formation on the spot of the coal-seam itself. All these trunks—those on the floor as well as at the roof of the seam—are cut off sharply at right angles, so that the former never show a continuation to the roof, or the latter a continuation to the floor. Moreover, it may be asserted that almost all coal-seams are separated from the rock-roof, and especially floor, by a stratum of very fine schist, of variable thickness, gradually passing into coal, and containing defaced fossils, which give evidence of having been drifted along.

J. W. P.

FUEL PROBLEMS.

Some Fuel Problems. By JOSEPH D. WEEKS. *Transactions of the American Institute of Mining Engineers*, 1895, vol. xxv., pages 943-955.

After a most interesting review of the enormous waste that is taking place every day in the mining and final uses of coal, the author concludes as follows:—Of the coal still remaining in the seams worked, not more than 30 per cent. on the average in the last 50 years has been won, that is, 70 per cent. has been lost. The percentage of the possible energy of coal utilized to-day does not exceed 10 per cent., if, indeed, it reaches 5 per cent. That is, but 10 per cent. of the 30 per cent. of the coal won in the mines, or but 3 per cent. of the possible energy imprisoned in the coal in America is ever released for useful work. The value of this lost energy must every year, in the United States alone, reach hundreds of millions of dollars. A low estimate of the value of by-products per ton of coal burned would be 2s. 1d. (50 cents). This would be £13,000,000 (\$64,000,000) on the bituminous coal mined in 1893. Is there not in this fuel-question a problem that demands most earnest work from mining engineers, and in which there is for the miner and manufacturer untold wealth?

A. W. G.

TEN YEARS' PROGRESS IN COKE MANUFACTURE AT DORTMUND.

Die Fortschritte der Kokafabrikation im Oberbergamtsbezirk Dortmund in den letzten zehn Jahren. By F. SIMMERBACH. *Zeitschrift für das Berg-, Hütten- und Salinen-Wesen im Preussischen Staate*, 1896, vol. xlv., pages 402-419, and 3 plates.

The mining district of Dortmund produces over 70 per cent. of the coke-output of the whole of Germany, namely, 6,400,000 tons out of a total of nearly 9,000,000 tons in the year 1894. The value of this latter amount is about £4,000,000, as against £1,950,000 in 1885. During those ten years, the export of German coke has grown from 633,900 tons to 2,282,000 tons. Nearly the whole of the coke produced in the Dortmund district is controlled by the Westphalian Coke Syndicate, which produced 5,398,612 tons in 1894, as against 2,826,697 tons in 1885; or, in other words, the production has doubled in ten years.

Of recent years there has been a strong movement in favour of coke-ovens that utilize the bye-products. Thus in 1885, out of a total of 5,852 coke-ovens in operation, there were 5,067 of the Coppée type and 306 that condensed the bye-products; in 1894 there were 7,866 coke-ovens, most of which were of the Coppée type, and 862 coke-ovens with provision for condensing bye-products, 1,000 more of the latter type having been constructed during 1895. The annual production of coke was 483 tons per oven in 1885, and 686 tons, or an increase of 41 per cent., in 1894.

The favourite ovens are those on the Coppée system, as modified by Dr. C. Otto, and Otto-Hoffmann and Collins ovens for the condensation of the bye-products. Ovens designed by Messrs. Brunck and Ruppert are also used. It is pointed out that a plant of 60 coke-ovens can produce 160 to 180 tons of tar and 40 to 100 tons of sulphate of ammonia per month.

H. L.

ESTIMATING PHOSPHORUS IN THE ASH OF COAL AND COKE.

Dosage du Phosphore dans les Cendres de Houille et de Coke. By LOUIS CAMPREDON. *Comptes Rendus de l'Académie des Sciences*, 1896, vol. cxxiii., pages 1000-1003.

As the whole of the phosphorus in the ash of coal is dissolved by iron in the blast-furnace, and as it is desirable to have the proportion of this element reduced to a minimum in the case of the finer qualities of cast iron, the accurate determination of the amount present in the ash of the fuel is a question of importance.

In comparing the various methods proposed for this purpose a number of tests were made with British coals, as follows:—

(1) *Solution in Hydrochloric Acid.*—The ash (0·6 or 1·2 grammes) was treated with excess of acid for 15 to 20 hours at a temperature of between 80° and 100° Cent., and after evaporating to dryness to remove the silica, and taking up the mass with a little nitro-hydrochloric acid, the solution was heated along with a further quantity of nitric acid to drive off the hydrochloric acid and made up to a bulk of 60 or 120 cubic centimetres, with cold water. For the estimation, 50 or 100 cubic centimetres of the filtered liquid were neutralized with ammonia, then rendered slightly acid with nitric acid, and treated with 20 to 30 cubic centimetres of ammonium molybdate to precipitate the phosphorus, the precipitate being allowed to subside at between 30° and 40° Cent. for a few hours and then washed with water containing 4 per cent. of nitric acid, dried at 105° Cent., and the resulting weight multiplied by 0·0163 to get at the weight of the phosphorus in the ash.

(2) *Fusion with Carbonates of the Alkalis*.—Here 0.6 gramme of the ash was fused for between 10 and 15 minutes with 3 grammes of potassium-sodium carbonate in a platinum crucible; cooled; taken up with acidified (hydrochloric acid) water; treated with the same acid in excess and evaporated to dryness to render the silica insoluble, the subsequent treatment being the same as practised in the former instance.

In the first set of five experiments, the hydrochloric acid process was first performed and the residue acted on by the fusion-method, with the result that between 4.5 and 17.5 per cent. (the mean being 10.5 per cent.) of the total weight of phosphorus present was found to have been overlooked by the acid method.

The second set of five tests was performed on part of the same ash previously heated to bright redness for an hour. In this case, the phosphorus undissolved by the acid ranged between 15.3 and 30.9—mean 23.04—per cent. of the total.

In the case of coke, the percentage unacted on by the acid varied between 8.4 and 25.3 per cent., the average being 15.74 per cent.

The inefficiency of the hydrochloric-acid method, especially in cases where the ash has been exposed to superheating, is evident, and the fusion-method with precipitation of the phosphorus by ammonium molybdate is therefore recommended on account of its superior accuracy.

C. S.

THE WORLD'S COPPER DEPOSITS.

Die Kupfererzlagerrstätten der Erde in geologischer, geographischer und wirthschaftlicher Hinsicht. By C. A. HERING. *Zeitschrift für das Berg-, Hütten- und Salinen-Wesen im Preussischen Staate*, 1897, vol. xlv., pages 1-90, and 1 plate.

The world's production of copper has increased from 151,000 tons in 1879 to 340,000 in 1895, that is to say has more than doubled in 16 years, the world's consumption having, however, kept pace with it, so that there is no increase in the visible stock, whilst the price has fallen in the ratio of 18 : 10. The author has compiled a fairly complete account of all the copper mines of the world, their positions, geology, and statistics.

South America.—From 1870 to 1880 Chili was the important copper-producing country, but since then it has fallen off greatly to about 20,000 tons per annum. The deposits are either primary quartz-veins in diorite or syenite, or secondary sandstone-impregnations as in Atacama. There are over 100 mines, and the ores average 15 to 18 per cent. In Bolivia, there is the wellknown Corro-corro mine, and in Venezuela that of Quebrada.

North America.—The United States in 1896 produced 203,210 tons of copper. The Michigan mines on the Keweenaw peninsula produce the wellknown Lake copper. The metal occurs practically always native in various rocks, richest in or near melaphyre. The chief mine, the Calumet and Hecla, produces ore with about 3 per cent. of copper; its output in 1896 was 35,126 tons. The next important mines are the Tamarack and the Quincy. The Atlantic mine is working successfully on ores containing 0.68 per cent. of metal. Montana produces copper in the Butte district from an area of 6 by 4 miles, the rocks being granite and rhyolite, traversed by series of veins running east and west. The chief mine is the Montana, which produced 99,775,294 lbs. of copper in 1895; next comes the Boston and Montana, with 60,746,000 lbs., all the others being much less important. In Arizona, there are four main districts, namely, Clifton-Morenci, Warren, Globe, and Black Range. Colorado produces some copper, but

largely from imported ores. The other States of the Union are not important producers. Canada produces copper chiefly from the deposits of nickeliferous copper pyrites and pyrrhotine of Sudbury, which occur at the contact of diorite with Huronian rocks or in the diorite itself. The whole Dominion of Canada produced 3,987 tons of copper in 1895. In Newfoundland, there are bedded deposits of cupriferous pyrites in chloritic schist at Tilt Cove and Betts Cove, Little Bay mine, formerly an important producer, has been closed down. In Mexico, the chief producer is the Boleo Company, working bedded deposits in Tertiary sandstone-conglomerates and tufas.

Africa.—The only important copper-mines now working in Africa are in the southern portion of the continent, mainly in Namaqualand, Damaraland, and Cape Colony, where the Cape Copper Company is working the Ookiep mines, and producing annually 20,000 tons of ore carrying 19 per cent. of copper. The production in the whole of Africa is given as 7,115 tons in 1895.

Asia.—Little is known about copper-mining on this continent, with the exception of Japan, whose production in 1895 is given as 18,430 tons; the chief mine is the Ashiwo mine in the province of Tochinghi, which produces about one-third of the total Japanese output. Regarding the rest of Asia, only very general and doubtful information is available.

Australasia.—The chief mines are in South Australia, near Adelaide; the principal mines are the Moonta and the Wallaroo, formed into one company since 1888, and producing annually about 6,000 tons of copper. The other colonies produce but little, and the total production of Australasia for 1895 is taken as 10,000 tons.

Europe.—This contains numerous and important copper-deposits, but none on a scale to compare with the larger works of the United States. It is, however, probable that the European mines will still be in full activity when those of North America are exhausted, a period that may not be far distant. In England, the production was formerly very important, but has been gradually decreasing to about 400 tons per annum in 1895. In the same year, 78,246 tons of copper were produced from imported, including native, ores. The chief copper-deposits of England are in Cornwall. Spain has been for many years the chief copper-producer of Europe, owing to the important deposits of cupriferous pyrites in the Huelva district. The chief mine is the Rio Tinto, producing annually 1,400,000 tons of ore, equivalent to 33,500 tons of copper. The ores occur in lenticular deposits at the contact of greenstone-porphry and clay-slates; these deposits are said still to contain 200,000,000 tons of ore. The Tharsis Company works its own mines and that of Calanos. The mineral district extends into Portugal, where the San Domingo mine is situated. France produces practically no copper, all the metal smelted there being obtained from imported ores. In Italy, the production is small, though there are wellknown mines at Monte Agordo, Monte Catini, and Monte Calvi; Italy's annual production is about 2,500 tons. Austria possesses a great number of deposits of copper-ore, though but very few are worked, so much so that the output in 1895 was only 1,110 tons. In Sweden, the well-known mine of Fahlun is the most important; the deposit consists of a flat lenticular mass, embedded in mica-schist rich in quartz; its annual output is about 500 tons of copper. Norway is rich in copper-deposits, Røros, Vigsnaes and Sulitjelma being the most important. Russia is also rich in copper, and produces about 5,000 tons annually; the Permian formation is impregnated with copper-ores over an extensive area, and the Urals, the Caucasus, and the Kirghiz Steppe contain many important deposits. Germany ranks fourth among the copper-producing states of the world; it pro-

duced in 1895 26,176 tons, of which about 9,000 tons were derived from imported ores. Prussia produces over 80 per cent. of the total, and its importance is largely due to the operations of the Mansfeld Company, working the wellknown Kupferschiefer or cupreous schist of the Lower Zechstein formation; this company extracts annually about 500,000 tons of ore, and produces from it about 14,500 tons of copper. At Stadtberge, in Westphalia, in the Kyffhäusergebirge, the Thuringian forest, and various other places, this same bed of cupreous schist is being worked. In the Harz mountains, the most important mine is that worked by the State at Rammelsberg, near Goslar.

From a review of the various sources of supply of copper and of the rate of consumption, the author concludes that the production has in recent years kept pace more and more with the demand, but conjectures that the latter is likely to rise more rapidly than the supply will be able to. H. L.

MINING FOR COPPER AND IRON PYRITES AT SCHMÖLLNITZ IN UPPER HUNGARY.

Der Kupfer- und Schwefelkies-Bergbau von Schmöllnitz im Zipser Comitat (Oberungarn). By JULIUS STEINHAUSZ. Berg- und Hüttenmännisches Jahrbuch, 1896, vol. xlv., pages 287-320, and 1 plate.

The author describes the geography of the Schmöllnitz mining district, which is traversed by the stream of that name. Its history is next related in much detail, dating from about the year 1280. The mines seem to have reached their highest stage of productiveness about the year 1780, and then to have gradually declined till the Government sold them all in 1890 to Messrs. Gerotte, Spitz & Co. for 1,000,000 gulden (about £100,000). This firm founded the Upper Hungarian Mining and Smelting Company, Limited, ("Oberungarische Berg- und Hüttenwerks-Actiengesellschaft"), to take over the mines and work the great pyrites deposits, the amounts produced having been as follows since that date:—

						Tons.
1890	...	...	...	...	...	38,388
1891	...	...	...	...	...	42,882
1892	...	...	...	...	...	43,173
1893	...	...	...	...	...	49,926
1894	...	...	...	...	...	58,610

The deposits of copper and iron pyrites form a series of irregular masses, lenticular or veinlike in shape, sometimes forming impregnations, and at times masses of very large size. They all occur in a belt of slate, chloritic, steatitic or quartzitic (phyllites), greenish-grey in colour, 250 to 330 metres (820 to 1250 feet) in thickness, bounded on either side by narrow bands of black graphitic slates. Eruptive rocks, that have been determined to be diorite or diabase, are also known. There are three main streaks of ore, parallel to the country-rock, striking east and west and dipping 70 to 80 degrees to the south. Their width varies from 1 to 18 metres (3 to 59 feet), and the partings between them are 20 to 40 metres (65 to 131 feet) wide. They have been followed and practically worked out for a length of over 3,000 metres (9,843 feet) along the strike and to a depth of 358.3 metres (1,175 feet). In addition to these ore-streaks, there are three huge lenticular masses of pyrites, *kiesstöcke*, known respectively as the hanging mass, the footwall mass, and the *Engelberti*. The footwall-deposit is the largest, being 400 metres (1,312 feet) along the strike, and 125 metres (410 feet) to the dip where it

pinches out, with a mean width of 26·5 metres (87 feet). The hanging deposit is 330 metres (984 feet) long, and extends to a depth of 70 metres (230 feet), whilst the *Engelberti* deposit is 175 metres (574 feet) long, and thins out at about 70 metres (230 feet) in depth. All these deposits consist of massive, coarsely foliated, pure iron pyrites, containing 0·5 to 2 per cent. of copper. The author considers that Prof. Vogt's views are applicable to these deposits, and that they are closely connected genetically with the eruption of diorite-diorite into the slates. The eruptive rocks are distant vertically 84 to 170 metres (275 to 557 feet) from the pyrites deposits. The slate belt is traversed by three main fissures, dipping about south-east, which all seem to have heaved the deposits more or less. The middle fissures seems to have caused the most faulting, and it is noteworthy that the ore-streaks were richest in the neighbourhood of this fault. These deposits are worked by means of a large number of adits and shafts. The method of mining is by horizontal slices from below upwards, the thickness of each floor being about 2·5 metres (8 feet). A main travelling way of this height is first driven about 2 metres (6 feet 6 inches) wide, and from it cross levels are driven to the foot and hanging walls from 8 to 12 metres (26 to 39 feet) apart, so as to cut up the deposit into pillars. These cross levels are then packed with deads brought in from the surface, and the pillars are got by taking off slices of about the same width, which are also packed. Hoisting presents no peculiarity, except that in some of the narrow tortuous shafts the ore is raised in bags of ox-hide, chiefly on account of the corrosive action of the mine waters. For pumping, columns of wood are used for suction-pumps, and force-pumps have been constructed of an alloy of copper, antimony, lead and tin. Considerable quantities of cement-copper are obtained by allowing the mine-waters to run through channels in which iron plates are placed; 30 to 50 tons of copper are thus obtained annually.

H. L.

ANACONDA ELECTROLYTIC COPPER REFINERY.

ANON. *The Engineering and Mining Journal* (New York), 1896, vol. lxxii., pages 271-274, with three illustrations.

The Anaconda refinery, which was designed by Mr. Hermann Thofehrn, was built in the most improved style, and is undoubtedly the best now in operation.

The electrolytic copper refinery has been running in full since January, 1896, and is turning out between 100 and 120 tons of copper daily, according to the output of the mines. The balance of the produce, from 80 to 100 tons, is refined in Baltimore. The total daily production of the Anaconda company is about 200 tons of copper. The refinery is built so that, in case of an emergency, it can easily handle the total product of 200 tons daily with the use of additional dynamos only.

The copper refinery also produces about 350,000 ounces of silver and about 1,500 ounces of gold per month, and this product is delivered to the market as fine bullion. The silver is 0·999 fine, and the gold 0·950 fine.

The Thofehrn new refining process is described, and illustrations are given of the engines and dynamos and of the electrolytic refinery.

J. W.

II.—BAROMETER, THERMOMETER, ETC., READINGS FOR THE YEAR 1896.

BY M. WALTON BROWN.

The barometer, thermometer, etc., readings have been supplied by permission of the authorities of Glasgow and Kew Observatories, and give some idea of the variations of atmospheric temperature and pressure in the intervening districts in which mining operations are chiefly carried on in this country.

The barometer at Kew is 34 feet, and at Glasgow is 180 feet, above sea-level. The barometer readings at Glasgow have been reduced to 32 feet above sea-level, by the addition of 0·150 inch to each reading, and the barometrical readings at both observatories are reduced to 32° Fahr.

The statistics of fatal explosions in collieries are obtained from the annual reports of H.M. Inspectors of Mines, and are also printed upon the diagrams (Plates XXVIII. and XXIX.) recording the meteorological observations.

TABLE I.—SUMMARY OF EXPLOSIONS OF FIRE-DAMP OR COAL-DUST DURING
1896, IN THE SEVERAL INSPECTION DISTRICTS.

	Fatal Accidents.			Non-fatal Accidents.	
	No.	Deaths.	Injured.	No.	Injured.
Durham	1	20	1	6	6
Liverpool	0	0	0	2	2
Manchester and Ireland	0	0	0	2	2
Midland	0	0	0	2	2
Newcastle-upon-Tyne ...	3	4	2	4	6
Scotland, East	3	4	0	25	30
Do. West	5	5	3	39	55
South Wales	8	73	15	29	38
South-Western	0	0	0	2	3
Staffordshire, North ...	0	0	0	3	4
Do. South	3	3	3	8	8
Yorkshire	2	64	3	3	5
Totals	25	173	27	125*	161

* 129 in official statistics.

TABLE II.—LIST OF FATAL EXPLOSIONS OF FIRE-DAMP OR COAL-DUST IN COLLIERIES DURING 1896.

1896.	Colliery.	Inspection District.	Deaths.	No. of Persons Injured.
Jan. 11, 12:30 p.m.	West Cannock ...	Staffordshire, South...	1	2
" 11, 12:45 "	Llanmorlais...	South Wales ...	2	3
" 27, 5:30 a.m.	Ferndale (Nos. 6, 7 & 8)	Do. ...	57	3
" 28, 2:30 p.m.	Blaennant ...	Do. ...	1	0
Feb. 1, 8:0 a.m.	Foxhole (Llanerch Slant) ...	Do. ...	1	0
" 4, 12:30 a.m.	Saltwells ...	Staffordshire, South...	1	1
" 10, 4:30 "	Axwell Park ...	Newcastle-upon-Tyne	2	1
" 29, 6:0 a.m.	Lanemark (No. 2) ...	Scotland, West ...	1	0
Mar. 28, 8:5 a.m.	Meiros ...	South Wales ...	3	7
" 30, 4:30 "	Straiton (Oil-shale)	Scotland, East ...	1	0
April 13, 10:0 p.m.	Brancepeth ...	Durham ...	20	1
" 27, 6:0 a.m.	Swalwell ...	Newcastle-upon-Tyne	1	1
" 30, 7:15 "	Micklefield ...	Yorkshire ...	63	3
May 6, 2:0 p.m.	Birkrigg ...	Scotland, East ...	1	0
June 8, 1:30 "	Carfin (No. 6) ...	Scotland, West ...	1	0
" 15, 7:0 a.m.	Bellfield ...	Do. ...	1	2
" 19, 3:30 p.m.	Abercave ...	South Wales ...	1	1
Aug. 4, 11:0 a.m.	Main (Bryncoch) ...	Do. ...	7	0
" 17, 8:45 "	South Duffryn ...	Do. ...	1	1
" 17, 12:30 "	Gawn ...	Staffordshire, South...	1	0
Sept. 16, 7:0 p.m.	Cornsillock ...	Scotland, East ...	2	0
" 26, 1:30 a.m.	Primrose Main ...	Yorkshire ...	1	0
Dec. 3, 6:30 p.m.	Drumsmudden ...	Scotland, West ...	1	1
" 5, 12:15 "	Seaton Delaval, Forster	Newcastle-upon-Tyne	1	0
" 29, 7:15 a.m.	Garscube (No. 1) ...	Scotland, West ...	1	0
Totals ...			173	27

TABLE III.—LIST OF NON-FATAL EXPLOSIONS OF FIRE-DAMP OR COAL-DUST IN COLLIERIES DURING 1896.

1896.	Colliery.	Inspection District.	No. of Persons Injured.
Jan. 3, 4:0 p.m....	British Rhondda ...	South Wales ...	1
" 4, 7:40 " ...	Braich-y-cymmer Darran	Do. ...	1
" 6, 1:30 p.m....	Corby Craigs ...	Scotland, West ...	2
" 7, 7:30 a.m....	Blair (No. 9) ...	Do. ...	2
" 7, 8:0 " ...	Gilbertfield (No. 2) ...	Do. ...	1
" 10, 1:30 p.m....	Bridgness ...	Scotland, East ...	1
" 13, 5:20 a.m....	Gartsherrie (Gartcloss)	Scotland, West ...	1
" 15, 9:0 " ...	Glenclelland (No. 1)...	Do. ...	1
" 16, 11:30 p.m....	Main (Bryncoch) ...	South Wales ...	2
" 20, 1:0 a.m....	Drumpeller (No. 4) ...	Scotland, West ...	2
" 20, 3:0 p.m....	Clynhebog ...	South Wales ...	1
" 21, 7:30 a.m....	Cymmer Glyn-Corrwg	Do. ...	1
" 25, 11:0 " ...	Coalbrook Vale ...	South-Western ...	1
" 27, 4:0 p.m....	Newton (No. 1) ...	Scotland, West ...	1
Feb. 6, 11:0 a.m....	Gwern ...	South Wales ...	1
" 8, 9:15 " ...	Darngavil ...	Scotland, East ...	1
" 10, 1:30 p.m....	Ferniegare ...	Do. ...	1
" 17, 11:0 a.m....	Whitworth Drift ...	South-Western ...	2
" 19, 7:30 " ...	Fairholm ...	Scotland, East ...	2
" 19, 6:0 p.m....	Lanemark (No. 2) ...	Scotland, West ...	1
" 28, 7:0 " ...	Straiton (Oil-shale) ...	Scotland, East ...	1

TABLE III.—*Continued.*

1896.		Colliery.	Inspection District.	No. of Persons Injured.
Mar.	2, 6.45 a.m....	Shut End ...	Staffordshire, South ...	1
"	2, 9.0 " ...	Lanemark (No. 2) ...	Scotland, West ...	2
"	3, 4.45 " ...	Holmside ...	Durham ...	1
"	3, 6.0 " ...	White Moss ...	Liverpool ...	1
"	3, 7.45 " ...	Aber Rhondda ...	South Wales ...	1
"	3, 8.0 " ...	Tuckies Pit ...	Staffordshire, North ...	1
"	3, 11.30 " ...	Common (No. 16) ...	Scotland, West ...	1
"	9, 11.30 p.m....	Ffrwd ...	Liverpool ...	1
"	11, 3.0 " ...	Bute Merthyr ...	South Wales ...	1
"	13, 4.15 " ...	Dinas Isha ...	Do. ...	2
"	14, 11.0 a.m....	West Cannock ...	Staffordshire, South ...	1
"	17, 8.0 " ...	West Merthyr ...	South Wales ...	1
"	23, 4.30 p.m....	Gilfach (Swansea Val.) ...	Do. ...	1
"	31, 12.30 " ...	Cannock Chase ...	Staffordshire, South ...	1
"	31, 3.0 " ...	Cwm Capel ...	South Wales ...	1
April	1, 3.30 " ...	North Skelton (Ironstone) ...	Durham ...	1
"	5, 7.0 a.m....	Trabboch ...	Scotland, West ...	3
"	6, 8.45 " ...	No. Motherwell (No. 1) ...	Do. ...	6
"	6, 6.0 p.m....	Varteg ...	South Wales ...	1
"	15, 12 noon ...	Straiton (Oil-shale) ...	Scotland, East ...	1
"	21, 7.0 p.m....	Shelton (No. 5), Race-course Pit ...	Staffordshire, North ...	2
"	22, 11.15 a.m....	North Skelton (Ironstone) ...	Durham ...	1
"	23, 6.45 " ...	Morlais Vale ...	South Wales ...	1
"	27, 1.0 p.m....	North Skelton (Ironstone) ...	Durham ...	1
"	27, 3.15 " ...	Newbridge, Rhondda ...	South Wales ...	1
"	27, 4.30 " ...	Ferniegare ...	Scotland, East ...	1
May	4, 9.0 a.m....	Hawne, New ...	Staffordshire, South ...	1
"	9, 12 noon ...	Cornailloch ...	Scotland, East ...	1
"	11, 8.0 a.m....	Westburn (No. 2) ...	Scotland, West ...	1
"	18, 1.30 p.m....	Newliston (Oil-shale) ...	Scotland, East ...	1
"	18, 9.45 " ...	St. John's ...	Midland ...	1
"	28, 6.30 a.m....	Straiton (Oil-shale) ...	Scotland, East ...	1
"	30, 10.10 p.m....	Hamstead ...	Staffordshire, South ...	1
June	1, 7.30 " ...	International (Garw Valley) ...	South Wales ...	3
"	6, 6.15 a.m....	Holytown (No. 8) ...	Scotland, West ...	1
"	6, 12.10 " ...	Glenclelland (No. 1) ...	Do. ...	1
"	6, 1.0 p.m....	Dumbreck (No. 2) ...	Do. ...	1
"	6, 7.0 " ...	Llantwit Red Ash ...	South Wales ...	1
"	8, 5.45 a.m....	Brownyside ...	Scotland, East ...	1
"	16, 6.15 p.m. ...	Darnagavil ...	Do. ...	1
"	18, 6.0 a.m....	Lanemark (No. 2) ...	Scotland, West ...	2
"	19, 3.45 p.m....	Blair (No. 9) ...	Do. ...	1
"	22, 10.15 a.m....	Bournehills ...	Staffordshire, South ...	1
"	29, 6.0 " ...	Billingsley ...	Staffordshire, North ...	1
"	30, 7.0 " ...	Cadder (No. 15) ...	Scotland, West ...	1
July	3, 5.0 " ...	Bedlington ...	Newcastle-upon-Tyne ...	2
"	3, 9.0 " ...	Rose Hill ...	Yorkshire ...	1
"	10, 9.0 " ...	Grimesthorpe ...	Do. ...	1
"	24, 2.45 p.m....	Birkrigg ...	Scotland, East ...	1
"	25, 4.0 a.m....	Auchenharvie (No. 1) ...	Scotland, West ...	1
"	27, 1.30 " ...	Twechar (No. 1) ...	Do. ...	1
Aug.	5, 3.30 p.m....	Home Farm ...	Scotland, East ...	1
"	7, 5.30 a.m....	Murdoctoun ...	Do. ...	1
"	7, 2.30 p.m....	Newton (No. 1) ...	Scotland, West ...	1
"	8, 2.0 " ...	Dalziel (No. 2) ...	Do. ...	1
"	10, 6.45 a.m....	Tannochside (No. 8) ...	Do. ...	1
"	12, 3.0 " ...	Souterhouse ...	Do. ...	1
"	12, 12 m'night	Birchgrove ...	South Wales ...	1
"	18, 2.30 a.m....	Straiton (Oil-shale) ...	Scotland, East ...	1

TABLE III.—Continued.

1896.		Colliery.	Inspection District.	No. of Persons Injured.
Aug.	18, 6-30 a.m....	Brands... ..	Midland	1
"	24, 5-15 " ...	Portland (No. 4) ...	Scotland, West ...	1
"	30, 11-0 " ...	Pont Henry	South Wales	1
"	31, 2-0 p.m....	Cadder (No. 15) ...	Scotland, West ...	1
Sept.	2, 8-15 a.m....	Blairhall	Scotland, East ...	1
"	2, 11-30 " ...	Gilfach (Swansea Val.)	South Wales	2
"	3, 6-15 " ...	Great Western ...	Scotland, West ...	1
"	9, 11-0 " ...	Newburgh	Newcastle-upon-Tyne	1
"	11, 7-15 " ...	Blackston	Scotland, West ...	2
"	22, 4-30 " ...	Swalwell	Newcastle-upon-Tyne	1
"	23, 11-0 " ...	Hattonrigg	Scotland, West ...	1
"	24, 12 noon ...	Brownyside	Scotland, East ...	3
"	25, 5-15 a.m....	Glyn	South Wales	1
"	25, 7-0 " ...	Scaitcliffe	Manchester	1
"	28, 6-30 " ...	Kenmuirhill	Scotland, West ...	1
Oct.	2, 8-0 " ...	Rankinston (No. 2) ...	Do.	1
"	3, 11-30 " ...	Cwrt-y-bettws ...	South Wales	1
"	6, 9-0 " ...	Newbattle	Scotland, East ...	3
"	8, 12-30 p.m....	West Ardsley	Yorkshire	3
"	8, 9-30 a.m....	Jarrow (No. 7) ...	Ireland	1
"	9, 1-0 " ...	Dinas Isha	South Wales	1
"	10, 12-15 " ...	Gartness	Scotland, East ...	1
"	16, 1-30 " ...	Pencoed	South Wales	3
"	17, 6-0 " ...	Stonelaw (No. 3) ...	Scotland, West ...	1
"	18, 11-0 p.m....	Newburgh	Newcastle-upon-Tyne	2
"	19, 9-30 a.m....	Fergushill (No. 22) ...	Scotland, West ...	1
"	21, 11-0 " ...	Blaennant	South Wales... ..	1
"	30, 10-30 " ..	Liverton (Ironstone)...	Durham	1
"	31, 6-0 " ...	Bannockburn (No. 1)...	Scotland, West ...	1
Nov.	7, 12-30 p.m....	Seafeld (Oil-shale) ...	Scotland, East ...	1
"	13, 8-0 a.m....	Haughhead	Scotland, West ...	1
"	16, 10-0 p.m....	Brynhenllis	South Wales	1
"	20, 7-30 a.m....	Newliston (Oil-shale)..	Scotland, East ...	1
"	21, 9-0 " ...	Sandwell Park	Staffordshire, South	1
"	25, 10-0 p.m....	Glyn	South Wales	1
"	27, 12-30 " ...	Gateside (No. 2) ...	Scotland, West ...	3
"	28, 7-30 " ...	Saltwell	Staffordshire, South	1
Dec.	4, 4-30 a.m....	Dumbreck (No. 2) ...	Scotland, West ...	2
"	4, 7-30 p.m....	Windsor Level	South Wales	2
"	13, 7-30 a.m....	Tower	Do.	2
"	15, 11-0 " ...	Kinneil	Scotland, East ...	1
"	25, 5-40 " ...	Addiewell (Oil-shale)..	Do.	1
"	25, 5-30 p.m....	Deans (Oil-shale) ...	Do.	1
"	29, 4-30 " ...	Westburn (No. 2) ...	Scotland, West ...	1
"	31, 6-30 " ...	Butterknowle	Durham	1
Total				161

TABLE IV.—BAROMETER THERMOMETER, ETC., READINGS, 1896.
JANUARY, 1896.

KEW.								GLASGOW.								
BAROMETER.					TEMPERATURE.		Direction of wind at noon	Date.	BAROMETER.				TEMPERATURE.		Direction of wind at noon	Date.
4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.	Min.	4 A.M.			10 A.M.	4 P.M.	10 P.M.	Max.	Min.			
1	30.121	30.173	30.154	30.163	49.0	36.8	S	1	29.841	29.889	29.849	29.807	50.1	44.9	S	1
2	30.134	30.175	30.161	30.180	50.1	44.6	S	2	29.795	29.876	29.917	29.966	50.1	43.8	SW	2
3	30.167	30.198	30.169	30.202	44.6	39.7	S	3	30.032	30.061	30.104	30.152	46.2	42.3	E	3
4	30.196	30.270	30.298	30.391	43.4	39.2	E	4	30.178	30.236	30.271	30.335	45.6	43.0	ENE	4
5	30.441	30.527	30.585	30.618	40.1	37.8	E	5	30.367	30.444	30.492	30.541	44.1	38.0	SW	5
6	30.628	30.654	30.616	30.625	36.3	36.0	E	6	30.550	30.564	30.548	30.578	43.9	38.5	WNW	6
7	30.627	30.665	30.668	30.706	36.3	32.0	NNE	7	30.599	30.659	30.671	30.717	48.3	41.4	WSW	7
8	30.684	30.686	30.679	30.729	44.9	34.4	NNE	8	30.734	30.815	30.850	30.946	43.5	35.3	WNW	8
9	30.776	30.868	30.864	30.888	39.4	33.6	NNE	9	30.969	31.020	30.984	30.932	37.0	29.7	W	9
10	30.831	30.768	30.688	30.677	37.0	33.9	N	10	30.855	30.821	30.779	30.777	36.4	29.4	W	10
11	30.645	30.636	30.578	30.521	43.1	34.8	N	11	30.737	30.689	30.575	30.491	40.2	31.9	SW	11
12	30.425	30.374	30.288	30.122	38.9	36.5	N	12	30.327	30.160	29.913	29.831	44.4	37.6	SW	12
13	29.982	29.834	29.840	29.712	44.1	37.7	N	13	29.747	29.714	29.605	29.391	39.0	34.1	WSW	13
14	29.358	29.343	29.626	29.758	49.0	36.5	N	14	29.359	29.547	29.602	29.489	37.7	33.1	ENE	14
15	29.656	29.521	29.453	29.714	52.3	35.2	SW	15	29.172	29.904	29.202	29.430	47.8	30.1	NW	15
16	29.906	30.009	30.009	30.050	46.6	37.8	W	16	29.530	29.679	29.680	29.697	47.6	35.2	W	16
17	30.098	30.131	30.145	30.205	51.8	42.9	W	17	29.732	29.772	29.775	29.839	50.3	46.0	W	17
18	30.209	30.218	30.180	30.201	47.1	43.3	SW	18	29.660	29.812	29.791	29.822	50.2	46.1	W	18
19	30.209	30.268	30.332	30.410	49.8	32.0	W	19	29.669	29.997	30.063	30.278	47.6	38.0	WSW	19
20	30.416	30.460	30.403	30.438	36.2	27.2	N	20	30.359	30.377	30.315	30.322	41.0	31.4	N	20
21	30.401	30.410	30.336	30.311	37.7	35.1	E	21	30.281	30.252	30.130	30.021	41.6	35.6	SW	21
22	30.240	30.238	30.218	30.279	43.6	31.8	E	22	29.963	30.112	30.161	30.222	45.2	31.2	NW	22
23	30.291	30.314	30.268	30.232	42.0	33.8	N	23	30.202	30.148	30.027	29.894	39.9	25.8	E	23
24	30.167	30.143	30.082	30.036	45.3	40.0	WSW	24	29.701	29.653	29.623	29.713	46.9	39.4	SW	24
25	29.835	29.913	29.886	29.952	50.8	42.7	SSW	25	29.733	29.795	29.854	29.981	44.7	40.6	ENE	25
26	30.016	30.179	30.241	30.316	46.9	44.9	NNW	26	30.026	30.062	30.005	29.971	46.2	39.1	E	26
27	30.319	30.338	30.273	30.244	46.7	43.6	S	27	29.929	29.959	29.739	29.559	50.9	40.8	SW	27
28	30.222	30.388	30.473	30.604	49.8	33.3	N	28	29.967	30.141	30.143	30.433	44.1	35.4	SW	28
29	30.693	30.811	30.827	30.879	45.7	30.7	NW	29	30.554	30.669	30.707	30.699	45.2	38.2	WSW	29
30	30.870	30.896	30.813	30.836	42.7	30.0	SW	30	30.671	30.697	30.693	30.719	46.8	43.2	WSW	30
31	30.806	30.796	30.740	30.703	43.2	36.7	W	31	30.704	30.684	30.629	30.600	45.0	39.8	W	31

FEBRUARY, 1896.

1	30.631	30.617	30.554	30.554	39.7	37.6	E	1	30.529	30.464	30.392	30.362	42.8	36.4	SW	
2	30.508	30.545	30.556	30.644	38.7	29.5	E	2	30.317	30.432	30.512	30.594	46.8	38.6	SW	
3	30.659	30.703	30.650	30.639	41.6	29.2	E	3	30.599	30.612	30.570	30.537	44.8	38.0	W	
4	30.583	30.604	30.572	30.584	41.3	32.8	SW	4	30.403	30.363	30.288	30.317	45.5	36.2	WSW	
5	30.535	30.552	30.524	30.557	47.9	32.6	WSW	5	30.305	30.327	30.356	30.392	49.2	43.3	W	
6	30.544	30.555	30.524	30.525	42.7	32.6	SSW	6	30.365	30.342	30.268	30.228	48.4	44.7	WSW	
7	30.493	30.481	30.424	30.378	41.2	36.0	SW	7	30.175	30.128	29.994	29.876	49.1	44.4	S	
8	30.279	30.230	30.145	30.127	52.3	35.7	SW	8	29.798	29.683	29.658	29.745	49.5	45.6	SW	
9	30.106	30.205	30.236	30.330	53.0	37.5	WSW	9	29.794	29.866	29.939	30.035	49.2	42.7	SW	
10	30.366	30.427	30.418	30.448	48.0	32.9	W	10	30.093	30.142	30.124	30.138	40.9	41.8	SW	
11	30.441	30.466	30.429	30.417	50.8	39.9	SW	11	30.144	30.157	30.104	30.137	50.5	47.2	SW	
12	30.368	30.315	30.241	30.284	55.5	38.6	W	12	29.928	29.925	30.018	30.207	50.4	44.1	W	
13	30.326	30.423	30.440	30.490	48.5	41.6	N	13	30.321	30.403	30.373	30.371	45.1	39.3	NE	
14	30.481	30.467	30.406	30.406	43.7	37.7	NNE	14	30.317	30.304	30.265	30.306	46.1	43.3	W	
15	30.370	30.415	30.444	30.522	47.8	40.3	N	15	30.331	30.413	30.430	30.499	50.3	43.0	W	
16	30.578	30.627	30.593	30.606	41.2	37.6	ENE	16	30.516	30.540	30.540	30.528	46.7	41.1	W	
17	30.557	30.523	30.422	30.391	42.0	32.5	E	17	30.469	30.431	30.436	30.299	44.9	35.8	S	
18	30.801	30.267	30.168	30.087	38.0	31.6	E	18	30.226	30.184	30.077	29.953	40.8	33.7	S	
19	29.959	29.863	29.734	29.704	54.0	32.0	SSE	19	29.790	29.617	29.471	29.433	46.6	31.1	NE	
20	29.650	29.686	29.692	29.731	53.1	47.6	S	20	29.420	29.485	29.552	29.632	47.8	42.9	W	
21	29.714	29.770	29.739	29.789	47.7	43.6	W	21	29.634	29.642	29.686	29.778	47.4	35.7	S	
22	29.823	29.960	30.036	30.149	43.5	32.2	E	22	29.852	30.008	30.103	30.220	42.0	36.5	E	
23	30.225	30.286	30.299	30.381	39.2	30.9	E	23	30.293	30.326	30.326	30.270	30.331	42.1	31.4	SE
24	30.419	30.457	30.423	30.432	40.7	27.7	E	24	30.331	30.362	30.308	30.273	40.0	31.4	SE	
25	30.353	30.332	30.203	30.121	31.6	24.8	E	25	30.176	30.095	29.973	29.940	40.1	31.2	SE	
26	30.012	30.053	30.054	30.133	35.5	22.8	NNE	26	29.967	30.045	30.078	30.144	35.8	29.0	ENE	
27	30.155	30.212	30.167	30.151	44.1	34.0	N	27	30.060	29.910	29.864	29.901	47.8	30.2	WSW	
28	30.115	30.139	30.118	30.191	55.0	42.7	WNW	28	29.877	29.926	29.995	30.097	46.3	39.5	WNW	
29	30.181	30.103	30.008	29.992	53.2	44.7	W	29	30.013	29.965	29.838	29.668	47.0	34.2	RNE	

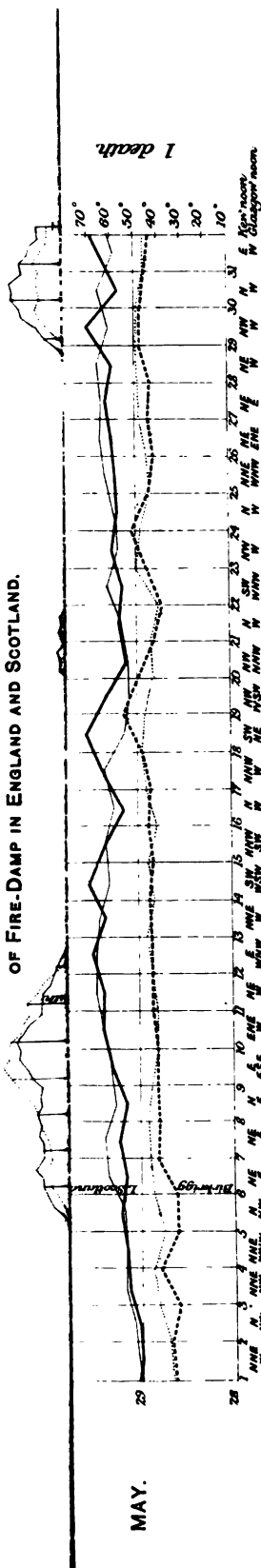
NOVEMBER, 1896.

KEW.							GLASGOW.								
BAROMETER.					TEMPERATURE.		Direction of wind at noon	BAROMETER.					TEMPERATURE.		Direction of wind at noon
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.	Min.		Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.	Min.	
1	29.677	29.725	29.770	29.826	47.4	35.0	N	1	29.925	29.983	29.988	30.002	47.1	38.3	NE
2	29.803	29.826	29.807	29.848	47.1	37.1	N	2	29.968	29.954	29.924	29.953	46.6	35.6	W
3	29.851	29.938	29.976	30.114	45.7	36.8	N	3	29.962	30.011	30.031	30.138	41.4	31.0	W
4	30.202	30.323	30.328	30.402	47.2	29.7	NNE	4	30.195	30.283	30.319	30.379	42.5	26.7	W
5	30.440	30.503	30.459	30.472	46.0	34.3	NE	5	30.409	30.474	30.457	30.443	43.3	37.2	W
6	30.410	30.364	30.228	30.150	46.5	29.0	NE	6	30.369	30.297	30.146	30.999	46.2	39.7	WSW
7	30.018	29.980	29.822	29.611	43.3	25.6	W	7	29.800	29.748	29.765	29.832	46.3	36.9	E
8	29.473	29.627	29.753	29.911	45.1	33.8	N	8	29.884	29.991	30.068	30.217	42.5	33.1	E
9	30.050	30.241	30.303	30.379	45.6	33.9	N	9	30.238	30.269	30.230	30.197	44.8	28.3	W, W
10	30.382	30.404	30.336	30.321	45.4	29.9	W	10	30.136	30.092	30.042	30.016	47.0	41.1	WSW
11	30.256	30.225	30.146	30.119	48.5	35.5	WSW	11	29.984	29.934	29.910	29.918	50.5	46.0	WSW
12	30.032	30.052	29.988	29.973	49.8	37.1	WSW	12	29.910	29.907	29.845	29.779	50.2	46.9	SW
13	29.925	29.920	29.838	29.843	47.6	30.2	S	13	29.661	29.557	29.475	29.604	48.4	43.8	S
14	29.814	29.758	29.512	29.188	47.1	40.7	SW	14	29.559	29.391	29.077	29.033	46.1	41.0	SSE
15	29.221	29.357	29.370	29.399	46.5	39.0	W	15	29.017	29.096	29.309	29.577	45.3	41.2	R
16	29.586	29.793	29.917	29.979	47.2	39.1	NE	16	29.774	29.951	30.015	30.057	47.9	42.0	NE
17	29.989	30.103	29.952	29.941	44.6	43.1	NNE	17	30.043	30.029	29.918	29.829	44.2	33.4	NE
18	29.902	29.898	29.863	29.975	45.4	39.0	SW	18	29.685	29.553	29.704	29.870	47.2	37.7	R
19	30.040	30.107	30.066	30.044	44.2	32.5	WSW	19	29.891	29.818	29.661	29.656	47.1	36.8	SW
20	29.957	30.054	30.165	30.313	49.5	36.0	NW	20	29.690	29.839	29.983	30.116	45.1	37.2	NW
21	30.395	30.476	30.477	30.523	48.5	32.0	NW	21	30.158	30.216	30.279	30.318	50.1	43.9	WSW
22	30.526	30.571	30.560	30.577	48.2	43.0	W	22	30.337	30.376	30.358	30.382	51.0	48.1	SW
23	30.575	30.583	30.544	30.568	48.2	31.2	W	23	30.380	30.420	30.430	30.489	50.9	46.7	SW
24	30.561	30.608	30.581	30.591	42.2	37.5	E	24	30.499	30.531	30.531	30.557	48.3	45.3	NW
25	30.549	30.524	30.432	30.419	41.3	40.1	NE	25	30.548	30.559	30.524	30.533	48.1	43.0	S
26	30.364	30.315	30.210	30.156	40.2	36.9	NE	26	30.497	30.493	30.440	30.408	43.4	39.1	E
27	30.083	30.095	30.006	29.811	44.4	36.2	NE	27	30.357	30.325	30.245	30.173	43.8	39.0	E
28	29.835	29.969	29.966	30.064	39.2	32.7	N	28	30.109	30.172	30.185	30.265	46.1	41.7	E
29	30.151	30.264	30.307	30.365	39.3	31.6	NNE	29	30.305	30.387	30.378	30.388	42.8	33.7	S
30	30.358	30.340	30.252	30.147	38.5	28.9	E	30	30.348	30.301	30.205	30.123	34.7	25.2	N

DECEMBER, 1896.

1	30.044	29.957	29.810	29.748	39.3	30.8	E	1	30.040	29.920	29.774	29.722	35.5	25.0	NE	
2	29.668	29.659	29.583	29.570	42.4	36.8	E	2	29.619	29.573	29.482	29.413	42.9	35.0	NE	
3	29.516	29.542	29.486	29.401	50.8	42.1	SW	3	29.303	29.276	29.194	29.182	47.3	41.6	SSE	
4	29.331	29.200	29.897	29.705	47.8	41.7	SE	4	29.159	29.193	29.171	29.102	45.9	38.9	E	
5	28.711	28.981	29.067	29.971	46.7	40.3	SW	5	28.930	28.961	28.791	28.707	44.4	41.9	E	
6	28.712	28.650	28.707	28.816	48.5	40.5	SW	6	28.755	28.856	28.845	28.882	42.8	36.3	E	
7	28.936	29.176	29.386	29.604	45.7	35.4	W	7	28.932	29.081	29.236	29.363	43.4	38.2	WNW	
8	29.699	29.738	29.715	29.637	46.2	32.4	S	8	29.445	29.461	29.469	29.513	46.8	35.8	S	
9	29.514	29.546	29.611	29.744	48.2	43.0	SSW	9	29.490	29.537	29.602	29.674	45.1	39.8	E	
10	29.872	29.895	29.798	29.801	48.7	37.8	S	10	29.667	29.656	29.542	29.514	46.1	42.9	ESE	
11	29.793	29.847	29.911	29.962	47.8	37.6	W	11	29.601	29.740	29.777	29.765	45.1	40.5	W	
12	29.949	29.848	29.646	29.639	45.5	29.4	S	12	29.678	29.533	29.443	29.515	42.1	38.0	SW	
13	29.738	29.768	29.592	29.287	43.4	36.0	SW	13	29.565	29.567	29.472	29.371	38.8	33.2	SW	
14	29.919	29.079	29.265	29.370	42.6	38.1	N	14	29.328	29.372	29.435	29.536	38.8	31.9	ENE	
15	29.458	29.649	29.744	29.814	40.2	29.4	N	15	29.608	29.677	29.664	29.655	40.4	31.9	W	
16	29.766	29.747	29.717	29.725	31.9	29.0	SW	16	29.634	29.643	29.565	29.562	41.1	26.2	SW	
17	29.698	29.666	29.559	29.527	33.4	28.1	SW	17	29.526	29.533	29.537	29.548	37.5	29.4	SW	
18	29.499	29.521	29.533	29.607	32.9	28.0	NW	18	29.595	29.672	29.688	29.747	38.2	27.7	SW	
19	29.659	29.731	29.805	29.942	36.1	27.4	N	19	29.789	29.896	29.961	30.098	37.8	31.1	NW	
20	30.042	30.164	30.181	30.182	38.2	30.3	N	20	30.165	30.238	30.264	30.262	38.9	25.2	E	
21	30.133	30.127	30.082	30.072	36.3	32.1	N	21	30.209	30.186	30.112	30.061	36.6	30.7	E	
22	30.049	30.072	30.070	30.127	40.6	31.2	S	22	29.956	29.962	29.963	30.050	35.5	30.2	W	
23	30.132	30.201	30.196	30.236	35.5	31.0	S	23	30.093	30.138	30.083	29.990	35.8	28.9	W	
24	30.210	30.196	30.028	29.877	42.2	26.2	S	24	29.810	29.700	29.546	29.601	44.4	34.3	W	
25	29.909	30.187	30.278	30.317	43.7	37.5	SNW	25	29.843	29.977	29.815	29.785	46.1	26.2	SSW	
26	30.286	30.253	30.151	30.116	50.7	41.2	SSW	26	29.773	29.685	29.473	29.630	53.6	45.9	SW	
27	30.175	30.354	30.398	30.368	51.8	39.7	W	27	29.875	30.013	30.066	30.040	46.1	36.1	W	
28	30.182	29.932	29.723	30.044	50.5	41.9	SW	28	29.840	29.762	29.961	30.108	41.5	35.0	N	
29	30.243	30.329	30.268	30.200	44.7	33.0	WSW	29	30.121	30.017	29.791	29.675	47.5	33.4	S	
30	30.103	30.054	29.970	29.871	49.8	43.8	SW	30	29.615	29.545	29.396	29.276	50.1	46.8	SSW	
31	29.898	30.071	30.110	30.151	49.7	44.4	WSW	31	29.522	29.670	29.713	29.786	49.5	40.6	SW	

DIAGRAM SHewing THE HEIGHT OF THE BAROMETER, THE MAXIMA AND MINIMA TEMPERATURES AND THE DIRECTION OF THE WIND AT THE OBSERVATORIES OF KEW AND GLASGOW, TOGETHER WITH THE EXPLOSIONS OF FIRE-DAMP IN ENGLAND AND SCOTLAND.



The firm top line is the Barometer reading at Kew, taken at 4 a.m., 10 a.m., 4 p.m., and 10 p.m.
 The dotted top line is the Barometer reading at Glasgow, taken at 4 a.m., 10 a.m., 4 p.m., and 10 p.m.
 The lower lines are the Maxima and Minima Temperatures at Kew and Glasgow, observed respectively at midnight and 9 p.m.

Kew lines are thick and Glasgow lines are thin.
 The figures attached to the districts show the Number of Deaths caused by the Explosions.

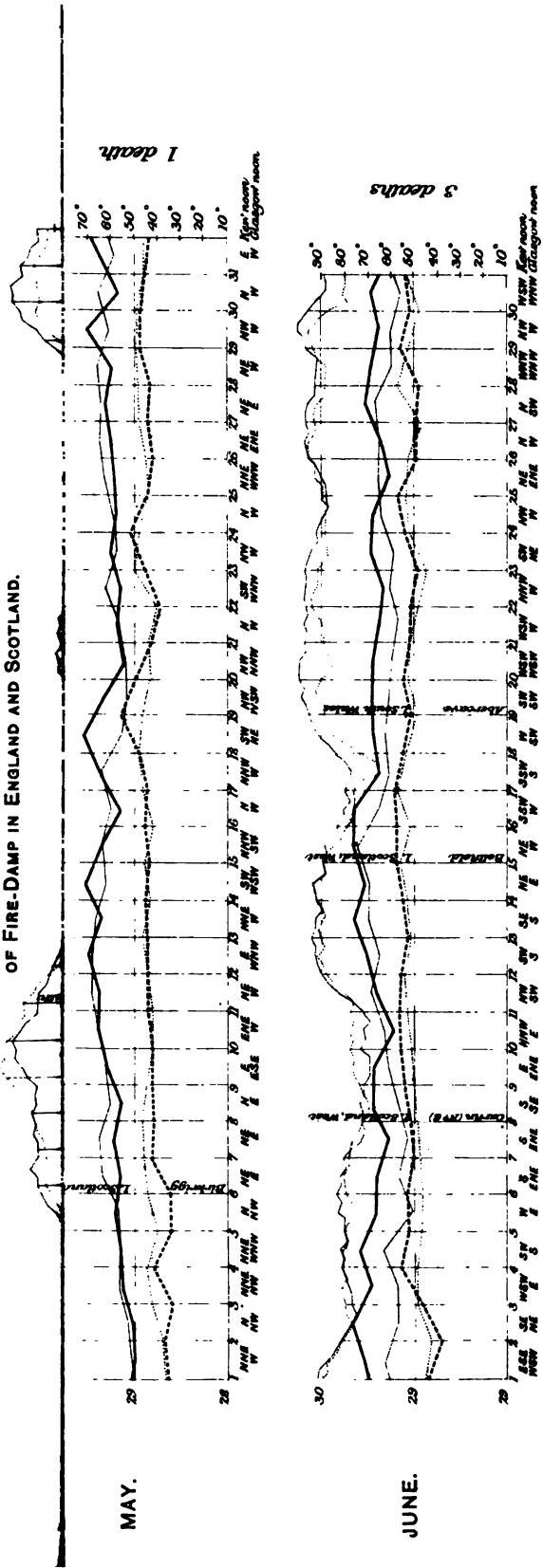
NOVEMBER, 1896.

KEW.								GLASGOW.							
BAROMETER.					TEMPERATURE.		Direction of wind at noon	BAROMETER.					TEMPERATURE.		Direction of wind at noon
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.	Min.		Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.	Min.	
1	29.677	29.725	29.770	29.826	47.4	35.0	N	1	29.925	29.983	29.988	30.002	47.1	38.3	NE
2	29.803	29.826	29.807	29.848	47.1	37.1	N	2	29.968	29.954	29.924	29.953	46.6	35.6	W
3	29.851	29.938	29.976	30.114	45.7	36.8	N	3	29.962	30.011	30.031	30.138	41.4	31.0	W
4	30.202	30.323	30.328	30.402	47.2	29.7	NNE	4	30.195	30.283	30.319	30.379	42.5	26.7	W
5	30.440	30.503	30.459	30.472	46.0	34.3	NE	5	30.409	30.474	30.457	30.443	43.3	37.2	W
6	30.410	30.364	30.228	30.150	46.5	29.0	NE	6	30.369	30.297	30.146	29.999	46.2	29.7	WSW
7	30.048	29.980	29.822	29.611	43.3	25.6	W	7	29.800	29.748	29.765	29.832	48.3	36.9	E
8	29.473	29.627	29.753	29.911	45.1	38.8	N	8	29.884	29.991	30.088	30.217	42.5	33.1	N
9	30.050	30.241	30.303	30.379	45.6	33.9	N	9	30.238	30.269	30.230	30.197	44.8	28.3	W-W
10	30.382	30.404	30.336	30.321	45.4	29.9	W	10	30.136	30.092	30.042	30.016	47.0	41.1	WSW
11	30.256	30.225	30.148	30.119	48.5	35.5	WSW	11	29.964	29.934	29.910	29.919	50.5	46.0	WSW
12	30.032	30.052	29.958	29.973	49.8	37.1	WSW	12	29.910	29.907	29.845	29.779	50.2	46.9	SW
13	29.925	29.920	29.838	29.843	47.6	30.2	S	13	29.661	29.557	29.475	29.604	48.4	43.3	S
14	29.814	29.758	29.512	29.188	47.1	40.7	SW	14	29.559	29.391	29.077	29.033	46.1	41.0	SSE
15	29.221	29.357	29.370	29.399	46.5	39.0	W	15	29.017	29.096	29.309	29.577	45.3	41.2	E
16	29.586	29.793	29.917	29.979	47.2	39.1	NE	16	29.774	29.951	30.015	30.057	47.9	42.0	NE
17	29.989	30.103	29.952	29.941	44.6	43.1	NNE	17	30.043	30.029	29.918	29.829	44.2	33.4	NE
18	29.902	29.898	29.863	29.975	45.4	39.0	SW	18	29.685	29.553	29.704	29.670	47.2	37.7	W
19	30.040	30.107	30.066	30.044	44.2	32.5	WSW	19	29.891	29.818	29.661	29.656	47.1	36.8	SSW
20	29.957	30.054	30.165	30.313	49.5	36.0	NW	20	29.680	29.639	29.963	30.116	45.1	37.2	NW
21	30.395	30.476	30.477	30.523	48.5	33.0	NW	21	30.158	30.216	30.279	30.318	50.1	42.9	WSW
22	30.526	30.571	30.580	30.577	48.2	43.0	W	22	30.337	30.376	30.358	30.382	51.0	46.1	SW
23	30.575	30.583	30.544	30.568	42.8	34.2	W	23	30.380	30.420	30.430	30.489	50.9	46.7	SW
24	30.561	30.608	30.581	30.581	42.2	37.5	E	24	30.499	30.531	30.531	30.557	48.3	45.3	NW
25	30.549	30.524	30.432	30.419	41.3	40.1	NE	25	30.548	30.559	30.524	30.533	48.1	43.0	E
26	30.364	30.315	30.210	30.156	40.2	36.9	NE	26	30.497	30.493	30.440	30.408	43.4	39.1	E
27	30.083	30.095	30.006	29.811	44.4	36.2	NE	27	30.357	30.325	30.245	30.173	43.8	39.0	E
28	29.835	29.969	29.996	30.064	39.2	32.7	E	28	30.109	30.172	30.185	30.265	46.1	41.7	E
29	30.151	30.264	30.307	30.365	39.3	31.6	NNE	29	30.305	30.387	30.378	30.388	43.8	33.7	E
30	30.358	30.330	30.252	30.147	38.5	28.9	E	30	30.348	30.301	30.205	30.123	34.7	25.2	S

DECEMBER, 1896.

1	30.044	29.957	29.810	29.748	39.3	30.8	E	1	30.040	29.920	29.774	29.722	35.5	25.0	NE	
2	29.668	29.659	29.553	29.570	42.4	36.8	E	2	29.619	29.573	29.482	29.413	42.9	35.0	NR	
3	29.516	29.542	29.486	29.401	50.8	43.1	SW	3	29.303	29.276	29.194	29.182	47.3	41.6	SSE	
4	29.331	29.200	29.897	28.705	47.8	41.7	SE	4	29.159	29.193	29.171	29.162	45.9	38.9	E	
5	28.711	28.981	29.067	28.971	46.7	40.3	SW	5	28.930	28.961	28.791	28.707	44.4	41.9	E	
6	28.712	28.650	28.707	28.816	48.5	40.5	SE	6	28.755	28.856	28.845	28.882	42.8	36.3	E	
7	28.936	29.176	29.386	29.604	45.7	35.4	W	7	28.932	29.061	29.236	29.363	43.4	38.2	WNW	
8	29.099	29.738	29.715	29.637	46.2	32.4	S	8	29.445	29.464	29.469	29.513	46.8	35.8	E	
9	29.514	29.546	29.611	29.744	48.2	43.0	SSW	9	29.490	29.537	29.602	29.674	45.1	39.3	S	
10	29.872	29.895	29.796	29.801	48.7	37.8	S	10	29.667	29.656	29.542	29.514	46.1	42.9	ESE	
11	29.793	29.847	29.911	29.962	47.8	37.6	W	11	29.601	29.740	29.777	29.765	45.1	40.5	W	
12	29.940	29.848	29.646	29.639	45.5	29.4	S	12	29.678	29.533	29.443	29.515	42.1	38.0	SE	
13	29.738	29.768	29.592	29.287	43.4	36.0	SW	13	29.565	29.567	29.472	29.371	38.8	33.2	SW	
14	29.919	29.079	29.265	29.370	42.6	38.1	N	14	29.328	29.372	29.435	29.536	38.8	31.9	ENE	
15	29.458	29.649	29.744	29.814	40.2	29.4	N	15	29.608	29.677	29.684	29.655	40.4	31.9	W	
16	29.766	29.747	29.717	29.725	34.9	29.0	SW	16	29.634	29.643	29.595	29.562	41.1	26.2	SW	
17	29.698	29.666	29.559	29.527	33.4	28.1	SW	17	29.526	29.533	29.537	29.548	37.5	29.4	SW	
18	29.499	29.521	29.533	28.607	32.9	28.0	NW	18	29.595	29.672	29.688	29.747	38.2	27.7	NW	
19	29.059	29.731	29.805	29.942	36.1	27.4	N	19	29.789	29.896	29.961	30.098	37.8	31.1	NW	
20	30.042	30.164	30.181	30.182	38.2	30.3	N	20	30.165	30.238	30.264	30.262	38.9	25.2	E	
21	30.133	30.127	30.082	30.072	36.3	32.1	N	21	30.209	30.186	30.112	30.061	36.6	30.7	E	
22	30.049	30.072	30.070	30.127	40.6	31.2	S	22	29.956	29.962	29.963	30.050	35.5	30.2	W	
23	30.132	30.201	30.196	30.236	35.5	31.0	S	23	30.093	30.138	30.063	29.990	35.8	28.9	W	
24	30.210	30.196	30.028	28.877	42.2	26.2	S	24	29.810	29.700	29.546	29.601	44.4	34.3	S	
25	29.909	30.187	30.278	30.317	43.7	37.5	SNW	25	29.843	29.977	29.815	29.785	46.1	36.2	SSW	
26	30.286	30.253	30.151	30.116	50.7	41.2	W	26	29.773	29.685	29.473	29.630	53.6	45.9	SW	
27	30.175	30.354	30.398	30.368	51.8	39.7	W	27	29.875	30.013	30.066	30.040	46.1	36.1	N	
28	30.182	29.932	29.723	30.044	50.5	41.9	SW	28	29.840	29.762	29.961	30.108	41.5	35.0	N	
29	30.243	30.329	30.268	30.200	44.7	33.0	WSW	29	30.121	30.017	29.791	29.675	47.5	33.4	W	
30	30.103	30.054	29.970	29.871	49.8	43.8	SW	30	29.615	29.545	29.396	29.276	50.1	46.8	SSW	
31	29.998	30.071	30.110	30.151	49.7	44.4	WSW	31	29.522	29.670	29.713	29.726	49.5	40.6	SW	

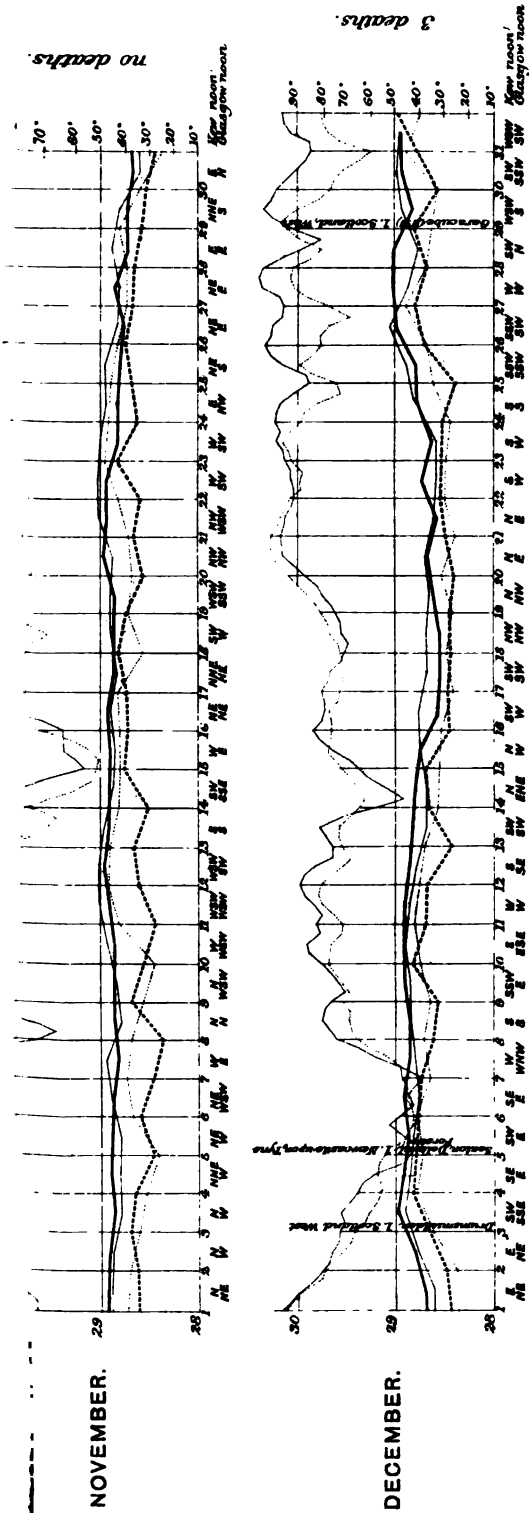
DIAGRAM SHewing THE HEIGHT OF THE BAROMETER, THE MAXIMA AND MINIMA TEMPERATURES AND THE DIRECTION OF THE WIND AT THE OBSERVATORIES OF KEW AND GLASGOW, TOGETHER WITH THE EXPLOSIONS OF FIRE-DAMP IN ENGLAND AND SCOTLAND.



*The Identified Inspections of Young Engineers
Transactions 1896-1*

**DIAGRAM SHEWING THE HEIGHT OF THE BAROMETER, THE MAXIMA AND MINIMA TEMPERATURES AND THE DIRECTION
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OF FIRE-DAMP IN ENGLAND AND SCOTLAND.**

VOL. XLII, PLATE XLII.

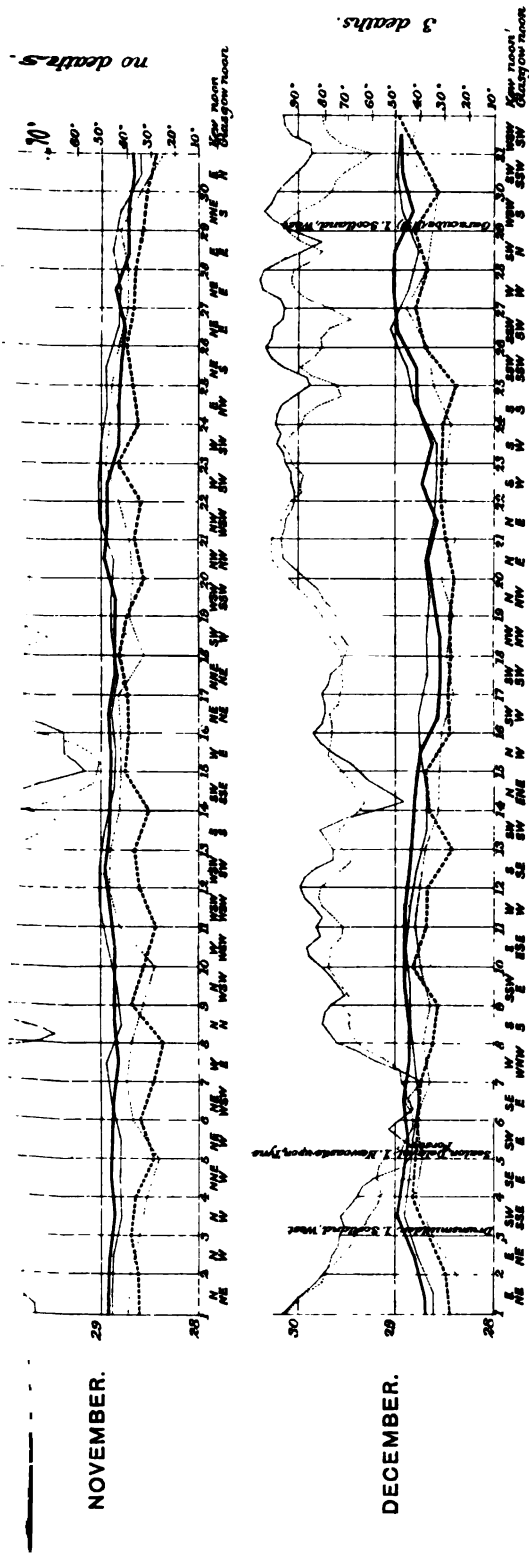


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The lower lines are the Maxima and Minima Temperatures at Kew and Glasgow, observed respectively at midnight and 9 p.m.
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The figures attached to the districts show the Number of Deaths caused by the Explosions.

*N. n. of England Institute of Municipal & Mechanical Engineers
Transactions 1896-1*

VOL. XLII, PLATE XLV.

DIAGRAM SHEWING THE HEIGHT OF THE BAROMETER, THE MAXIMA AND MINIMA TEMPERATURES AND THE DIRECTION OF THE WIND AT THE OBSERVATORIES OF KEW AND GLASGOW, TOGETHER WITH THE EXPLOSIONS OF FIRE-DAMP IN ENGLAND AND SCOTLAND.



The firm top line is the Barometer reading at Kew, taken at 4 a.m., 10 a.m., 4 p.m., and 10 p.m.
 The dotted top line is the Barometer reading at Glasgow, taken at 4 a.m., 10 a.m., 4 p.m., and 10 p.m.
 The lower lines are the Maxima and Minima Temperatures at Kew and Glasgow, observed respectively at midnight and 9 p.m.
 Kew lines are thick and Glasgow lines are thin.

The figures attached to the districts show the Number of Deaths caused by the Explosions.

INDEX TO VOL. XIII.

EXPLANATIONS.

The — at the beginning of a line denotes the repetition of a word; and in the case of Names, it includes both the Christian Name and the Surname.

Discussions are printed in *italics*.

The following contractions are used :—

C.—Chesterfield and Midland Counties Institution of Engineers.

M.—Midland Institute of Mining, Civil and Mechanical Engineers.

S.—Mining Institute of Scotland.

N. E.—North of England Institute of Mining and Mechanical Engineers.

N. S.—North Staffordshire Institute of Mining and Mechanical Engineers.

S. S.—South Staffordshire and East Worcestershire Institute of Mining Engineers.

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